[VOLUME V.
NUMBER 4.]

[ENTERED AT THE]

JANUARY, 1888.

[ANNUAL SUBSCRIPTION
IN ADVANCE $10.00
SINGLE COPIES . $1.00]

TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

SPECIAL MEETING, DECEMBER 6TH, 1887.

SUBJECT:

Phenomena of Interpolation in the Induction Coil.

BY WILLIAM STANLEY, JR.

NEW YORK CITY:
PUBLISHED BY THE INSTITUTE.
A. W. Tuer, Secretary,
12 West 31st Street.

OFFICERS AND MEMBERS OF THE COUNCIL.

1887-8.

PRESIDENT:

T. COMMERFORD MARTIN,
Term expires 1888.

PAST-PRESIDENTS:

DR. NORVIN GREEN, 1884-5-6.
FRANK L. POPE, 1886-7.

VICE-PRESIDENTS:

Dr. NORVIN GREEN,
Term expires 1888.

FRANK L. POPE,
Term expires 1888.

Prof. ELIHU THOMSON,
Term expires 1888.

Col. ROWLAND B. HAZARD,
Term expires 1888.

GEORGE C. MAYNARD,
Term expires 1888.

Prof. W. A. ANTHONY,
Term expires 1888.

MANAGERS:

CHARLES L. BUCKINGHAM,
Term expires 1888.

Prof. CYRUS F. BRACKETT,
Term expires 1889.

Prof. B. F. THOMAS,
Term expires 1889.

C. O. MAILLOUX,
Term expires 1889.

DAVID BROOKS,
Term expires 1888.

SCHUYLER S. WHEELER,
Term expires 1890.

EDWARD P THOMPSON,
Term expires 1888.

JOSEPH WETZLER,
Term expires 1890.

T. BENEDICT HERZOG,
Term expires 1889.

A. O. FOWLER,
Term expires 1890.

CAPTAIN O. E. MICHAELIS, U.S.A.
Term expires 1889.

WILLIAM LEE CHURCH,
Term expires 1890.

TREASURER:

GEORGE M. PHELPS, Jr., 11 Wall Street, New York.
Term expires 1888.

SECRETARY:

RALPH W. POPE, 19 Day Street, New York.
Term expires 1888.

Copies of the Rules, application blanks, membership lists and general information regarding the Institute may be obtained by addressing the Secretary.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

VOL. V. New York, January, 1888. No. 4.

SECRETARY'S BULLETIN.

The Index of Current Electrical Literature, begun in the December issue, has met with very general approval. Several suggestions for improvement have been made, which will be introduced as the work progresses.

At the regular meeting of Council, held December 6th, the following named gentlemen were elected to associate membership of the American Institute of Electrical Engineers;

Wilfrid H. Fleming, Sawyer-Man Electric Co., Decatur, Ala.

F. T. J. Haynes, Superintendent Telegraphs B. & E. section Great Western R'y., Taunton, England.

Wirt B. Harvey, Night Chief Operator, W. U. Telegraph Co., Memphis, Tenn.

A. A. Knudson, Superintendent and Electrician, Nova Scotia Telephone Co., Halifax, N. S.

C. A. Coffin, Vice-president Thomson-Houston Electric Co., 178 Devonshire St., Boston, Mass.

J. C. Chamberlin, Chief Electrical Engineer, Sawyer-Man Electric Co., 32 Nassau St., New York.

Chas. Lever, Electrical Engineer, Bowdon, Cheshire, England.

Howard L. Browning, Agent Edison Electric Light Co., Albany, N. Y.

William Stanley, Jr., Electrician, Westinghouse Electric Co., Great Barrington, Mass.

E. Wilbur Rice, Jr., General Superintendent and Consulting Electrician, Thomson-Houston Electric Co., Lynn, Mass.

J. Day Flack, Assistant, Testing Department, Edison Lamp Co., Harrison, N. J.

W. Forman Collins, Electrician, The Hawkeye Electrical Mf'g. Co, New York.

The following associate members were upon recommendation of the Board of Examiners transferred to full membership:

Leo Bock, Jr., New York.
C. S. Bradley, Yonkers, N. Y
William Standford, Cape Town, Africa.
B. Bayly, Cape Town, Africa.
Prof. Edward L. Nichols, Ithaca, N. Y.
Ernest Thurnauer, Hamburg, Germany.
William M. Schlesinger, Philadelphia, Pa.
Anthony Reckenzaun, London, Eng.
Charles Cuttriss, New York.
Georges d'Infreville, New York.
James Hamblet, New York,

The next meeting of the Institute, to be held on Tuesday, January 10th, will be of a very interesting nature, as a paper is to be presented by Mr. Willard E. Case, of Auburn, N. Y., on "Electric Energy from Carbon without Heat." Mr. Case, who has made extensive investigations in thermo-electricity and has succeeded in utilizing simple coal as one of the elements of a chemical battery, will give the results of his experiments and discoveries. One of the recent improved batteries will be exhibited, illustrating practically the new departures in this unfamiliar field of research and application.

Special Meeting.

Held at the House of the American Society of Civil Engineers, 127 East 23d Street, New York, December 6th 1887.

The meeting was called to order at 8 p.m., by the President of the Institute, Mr. T. C. Martin.

The President:—The subject which we have before us this evening, is one of the first importance. I therefore have much pleasure in asking Mr. William Stanley, Jr., the electrician of the Westinghouse Electric Company to read us his paper on the "Phenomena of Retardation in the Induction Coil."

PHENOMENA OF RETARDATION IN THE INDUCTION COIL.

BY WM. STANLEY, JR.

This paper will attempt to emphasize the time relations of the alternating E. M. F.'s. and currents in the induction coil. Any description of the phenomena of retardation accompanying the inductive effects of currents would necessarily be incomplete and unintelligible without a clear conception of the fundamental principles of the induction coil. This must be my excuse for briefly recalling to you the rudiments of the induction system.

An alternating E. M. F. differs from a direct E. M. F. in two important points: It varies continuously, and its direction or polar tendencies alternate.

To illustrate graphically the various values of an alternating E. M. F. and the attending phenomena, it is usual to plot a series of curves above and below a straight line. This line, when divi-

ded in equal divisions, may be taken to represent successive periods of time (See Fig. 1). Starting at the point A, the E. M. F. is seen to rise rapidly above the line $A\ X$ in a gentle curve (the particular curvature of which depends on the construction of the generator), until at 9 reaches its highest point; thence it flows downward in a similar but reverse curve, until it again reaches the line $A\ X$, and, continuing downward, finally attains a sub-maximum at C. From this point it rises again, crossing the line $A\ X$ once more at D, whence a repetition of the former curves occur.

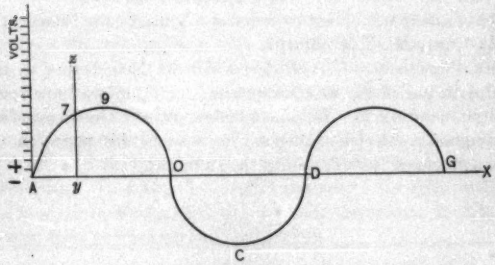

Fig. 1.

The E. M. F, of the alternating current at any particular time can be determined by the distance of the curved line above or below $A\ X$ at that time. For instance, suppose we wish to determine the E. M. F. at any time, y. Through y draw $y\ z$ perpendicular to $A\ X$, cutting A 9 at 7. Then 7 y represents the E. M. F. applied to the circuit at the time y.

From an examination of the curve it will be seen that at stated intervals of time A, O, D, G, there is no E. M. F. applied to the circuit; and, if the curves above the line $A\ X$ represent E. M. F.'s applied in one direction, those below the line $A\ X$ represent E. M. F.'s in the opposite direction. Hence adjacent E. M. F.'s alternate in direction, and hence the term alternating currents.

There is a general misunderstanding to the effect that the alternate current dynamo is less economical than is the direct current generator. This is not so; there is a little difference, it is true, but the difference is, I believe, in favor of the alternate current machine. Let us take a dynamo field, for example, that of a

simple direct current type of dynamo, and separately excite it with a constant current; let us now wind two armatures of identical dimensions, one for direct and one for alternate currents, and arrange to run them at the same speed; and let the windings of the two armatures be identical in size and number of turns of wire. Now the E. M. F. produced in these two armatures will be found to be, for the direct current armature;

E. M. F.	X volts.
Resistance of the armature	R ohms.
Amperes per section of winding	A amperes.

And because the armatures are identical we have for the alternate current dynamo:

E. M. F.	$2\,X$ volts.
Resistance of the armature	$4\,R$ ohms.
Amperes per section of conductor	$\frac{1}{2}\,A$ amperes.

Thus the direct current dynamo will generate $A\ X$ watts, and

Fig. 2.

the alternate current dynamo $2\ X \times \frac{A}{2}$ or $A\ X$ watts also. Hence the capacities of the armatures are equal.

The loss of energy in the armatures will be, for the direct current dynamo, $A^2\ R$ watts. For the alternate current dynamo $\left\{\frac{A}{2}\right\}^2 \times 4\ R$, equals $\frac{4\ A^2\ R}{4}$, or $A^2\ R$ watts. From this we learn that the losses in the armatures are equal. It is stated, however, that owing to self-induction, Foucault currents, or something else, these figures do not represent the actual waste of energy. The waste of energy by self-induction in the direct current dynamo occurs when a brush on the commutator touches two adjacent strips at the same time, as in Fig. 2. The arrows indicate the direction of the induced currents and show that at that time all the E. M. F. of the short circuited coil is wasting

current on a short circuit through the brush. What now is the loss in the alternate current dynamo through self-induction?

In the direct current dynamo the current flowing through the armature coils magnetizes the armature with a polar line at an angle to the polar line of the field. These armature poles maintain a constant position relative to a fixed point, and are of a constant value. In the alternate current dynamo, the current in the armature rises above and falls below a zero value periodically; hence the iron in the armature has periodic polar tendencies at an angle to the polar line of the field.

I shall endeavor to show that instead of wasting energy by periodically polarizing the armature, the E. M. F. devoted to this purpose is at first temporarily stored and subsequently returned. As is well known, a certain period of time is required to establish a given magnetic charge in iron, which time is direct-

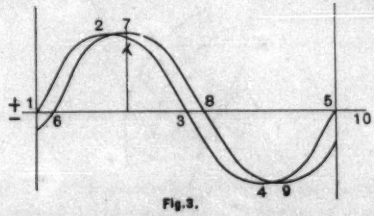

Fig. 3.

ly proportional to the degree of magnetization to be attained.

If, therefore, we plot a curve, the abscissæ representing time and the ordinates the degree of magnetization, and if we apply this curve to the curve of E. M. F. producing it, we have two similar curves separated from one another by a given period of time, as shown in Fig. 3, where 1, 2, 3, 4, 5 represents the curve of E. M. F., and 6, 7, 8, 9, 10 the corresponding curve of magnetization.

When the coil on the alternate current armature leaves a pole of the field (during rotation) the lines of force threading it rapidly diminish, and by induction generate an E. M. F. in the coil. The rise of E. M. F. and consequent flow of current in the coil is attended by a magnetic polar effect in the iron core, which not only increases while the E. M. F. is rising from 1 to 2, but continues to increase, attaining its maximum value when the E. M.

F. has fallen to *K*. Up to this time, namely, the time when the magnetic charge is maximum, energy has been expended upon the iron core; but notice, that at this time the charge on the iron core is superior to the charge producable by the E. M. F. at that instant; consequently, the charged core does positive work upon the E. M. F., if I may use the expression, and in doing this decreases its own value.

This auxiliary E. M. F. developed by the magnetized core upon the armature conductor assists the E. M. F. proper; that is, the E. M. F. developed by the field magnets. Thus the energy devoted to magnetizing the armature, during the rise of wave of E. M. F., is returned as E. M. F. during the fall of potential. We may assume that the wave is shifted along or retarded. Fig. 3 illustrates this retardation. 1, 2, 3, 4, 5, is the curve representing the position of a wave of E. M. F., without taking into

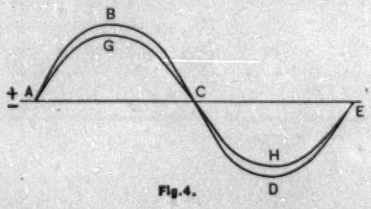

Fig. 4.

consideration the effect of the iron core, while 6, 7, 8, 9, 10 is the curve-wave of E. M. F. which has been retarded, by reason of the magnetic charge on the iron from the theoretical position, 1, 2, 3, 4, 5.

The curve of E. M. F. of a coreless armature is quite different; here, as before, the theoretical curve is *A*, *B*, *C*, *D*, *E*, Fig. 4. Let us see what the effect of self-induction is in this case.

We know that the self-induction is proportional, among other things, to the current flowing at a given time, Now, at the time *A* no current flows; hence, there is no self-induction. But as the E, M. F. rises, and current is driven through the coil, the self-induction or counter E. M. F. prevents the E. M. F. from attaining its theoretical value. It does not delay the E. M, F from its theoretical time position, as is the case with an iron core, but prevents the E. M. F, from attaining its theoretical

maximum value at any time. The real curve of E. M. F. in this case would be *A*, *G*, *C*, *H*, *E*, Fig. 4. This curve shows that there is no waste of energy due to counter E. M. F., but that the armature output is reduced by self-induction. An iron core, therefore, causes the counter E. M. F. to oppose the E. M. F. proper only during one-half a period, and allows it also to assist the E. M. F. proper during the other half period in the phase.

It is evident that the time of retardation, viz., the distance between 1, 2, 3, 4, 5 and 6, 7, 8, 9, 10, Fig. 3, depends on the quantity of current flowing through the armature coils as well as on the core. I have described this point at length, as there is a general, although false, impression that the iron core of an alternating armature necessarily wastes energy.

We may roughly compare the theoretical efficiencies of the direct and alternating dynamos, as follows The output is equal; the waste of energy in armatures due to $C^2 R$ is equal. The waste due to self-induction is greater for direct than alternating dynamos, with properly constructed iron cores.

Faraday's law of induction may be stated as follows: The variation of the magnetic field surrounding a conductor induces an E. M. F. in that conductor. A variable field is produced by a variable current, and hence, a conductor carrying an alternating current will induce an E. M. F. in another conductor residing in the same field.

Let us note the values of the E. M. F.'s in the inducing or primary, and induced or secondary circuits, at the same time, and first when no current is flowing. The curve, *A*, *B*, *C*, *D*, *E*, Fig. 5, represents, as before, the alternating applied E. M. F. Now, the induced E. M. F. will be a maximum at the time when the inductive effect of the primary current is a maximum, and the inductive effect of the primary will be greatest when its E. M. F. is changing most rapidly. Evidently this will occur near the zero line *A X*; for the E. M. F. will vary the most when passing from a finite value to zero, or from zero to any finite value. Hence the inductive effect of the primary and the E. M. F. developed on the secondary circuit will be a maximum when the primary E. M. F. is least.

Fig. 5 represents the time relation of the primary and secondary E. M. F.'s when no current is passing. The position of maximum E. M. F. of the secondary is, as you see, one-fourth of a complete period behind that of the primary. Now, a moment's

consideration will show that the secondary circuit is simply the receptacle of an E. M. F., and, when no current is flowing in it, plays no part in the inductive phenomena.

The primary circuit evidently will induce in itself an E. M. F. in the same manner that it impresses the E. M. F. on the secondary circuit. Hence, in any circuit to which is applied an alternating E. M. F., we have two phases of E. M. F.; the one, the applied; the other, the self-imposed; the points of equal value in

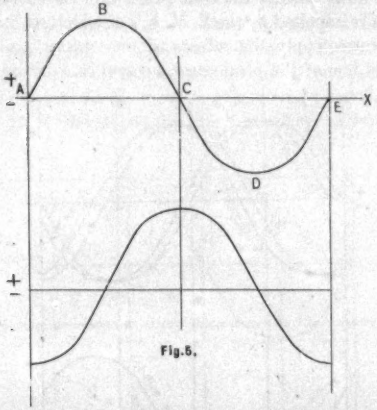

Fig.5.

each being distant from each other one-fourth of a complete period, when practically no current is flowing. This self-impressed E. M. F. is called "self-induction," or counter E. M. F. When two or more coils are wound together so as to act collectively, the effect of the one upon the other is termed "mutual" induction. We now see why, when an alternating E. M. F., of, say, 1,000 volts, is suddenly applied to a coil whose resistance is low, as, say, 1 ohm. the coil does not receive the quantity of current destined for it by Ohm's law. The kinetic E. M. F. is very small because it is the difference between the applied and counter E. M. F.'s.

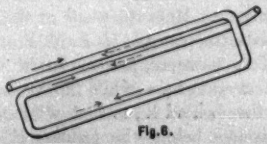
Fig.6.

Fig. 6 shows a wire wound on itself or coiled. The full arrows

indicate the direction of the applied E. M. F., the dotted arrows the counter E. M. F. In the two adjacent turns one impresses a counter E. M. F. on itself and also a counter E. M. F. on the other and the other impresses a counter potential on itself and on the first. Hence in two coils of wire we have four impressed counter E. M. F.'s. This is commonly stated as the self-induction; and is proportional to the square of the number of turns,

We will now consider the time position of the currents flowing through coils impelled by the E. M. F.'s of which we have spoken, and endeavor to apply the effects of the various positions they assume to a few of the phenomena noticed in working induction

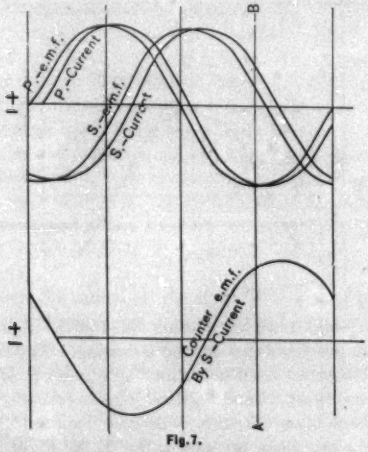

Fig. 7.

coils with different current strengths.

Evidently, when little current is flowing over a conductor, the self-induction and retardation are small; hence the curve of the current nearly coincides with the curve of E. M. F. Fig. 7 illustrates the positions. Here the phase of the primary current nearly coincides with the phase of its E. M. F. The curve of the secondary E. M. F. is, however, just one-fourth of a period later than the primary current phase, while the curve of the secondary current is still farther behind it; so that, while the primary current phase is x distance behind the primary E. M. F. phase, the secondary current phase is $2x$ plus one-fourth of a period behind

the primary E. M. F. phase. This delay reacts on the primary E. M. F. The lower curve in Fig. 7 is the curve of the counter E. M. F. developed by the secondary current upon the primary circuit. It will be noticed that it no longer exactly opposes the phase of the applied E. M. F., for the time line *A B*, passing through the maximum position of the primary E. M. F., cuts the counter E. M. F, curve at a point before its maximum value is attained.

Fig. 8 shows an extreme case. Here the curve of the primary current is one-eighth of a period behind its E. M. F. Consequently, the curve of secondary current is one-half a period behind the primary E. M. F., *i. e.*, $\frac{1}{8} \times 2 + \frac{1}{4}$; and the curve of counter E. M. F. developed by the secondary current is $\frac{1}{4}$ of a

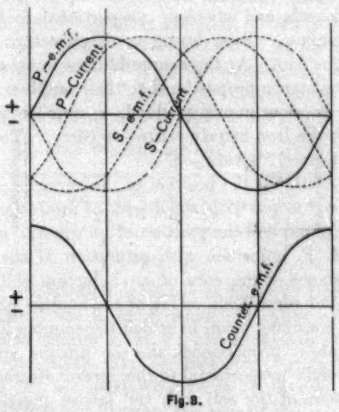

Fig. 8.

period behind the primary E. M. F.

We are now prepared to understand why the counter E. M. F. developed in the induction coil varies in its counter effect as current is abstracted from the coil. The reason is simply that its position of counter effect is dependent on the curve of its producing current, and as the current occupies a variable position relative to the applied E. M. F,, the counter E. M. F. successively occupies positions of lesser counter effect until eventually it has no counter effect whatever.

These phenomena are taken advantage of in the operation of induction coils. If a constant E. M. F. be applied to the primary circuit of a converter, successive increments of current will be allowed to occupy this primary circuit as successive quantities of current are abstracted from the secondary circuit; because these currents push along out of the way the opposing counter E. M. F., and consequently the kinetic E. M. F. attains correspondingly greater values.

Thus far we have considered only two factors of self-induction and retardation, viz., the number of turns of the conductor, and the quantity of current flowing; but there is another factor, most important, and that is, the resistance of the magnetic circuit.

The magnetic resistance of iron is, as you know, similar to the resistance of any other conductor, in that it is directly proportional to the length, and inversely proportional to the sectional area of the circuit. This, however, is only true for limited values of magnetism. As the magnetic lines traverse a core they encounter a resistance proportional to their number at first; but if more lines be continuously added, a number is eventually reached which the iron utterly refuses to carry. This degree of magnetism is termed "saturation."

It can be shown that the position of the curve of counter E. M. F. is directly connected with the degree of saturation of the core, so that with a given coil the position of no counter effect of the counter E. M. F. coincides with saturation of the core. The magnetic resistance of the core of an induction coil determines, then, the limit of retardation or lag of the current phase. Hence, if we wish to construct a coil in which the counter E. M. F. shall always be inversely proportional, and the kinetic, applied E. M. F., always directly proportional to the current abstracted from it, we make the core of the coil with the lowest possible magnetic resistance. Such a coil, when supplied with a constant difference of potential, will furnish at its secondary terminals an approximately constant E. M. F. It is also evident that a coil having a limited section of core supplied with a constant current may deliver a constant E. M. F. on its secondary terminals, provided the field produced by the constant current is sufficient to saturate the core.

I noticed these phenomena several years ago when experimenting with a series system for lighting. Mr. O. B. Shallenberger has applied this saturation effect in a most striking manner.

He connects a number of incandescent lamps, say four, in series, attaching their outer terminals to a source of constant alternating E. M. F. Fig. 9. Around each lamp is shunted a self-induction

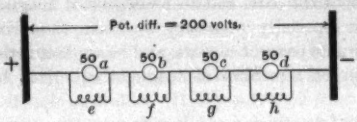

Fig 9.

coil, so proportioned that an E. M. F. of say 100 volts will saturate the core of the coil. If, now, a lamp be turned off, its current is diverted through the shunted coil, which offers a counter E. M. F. of 100 volts. We would naturally expect that the light in the remaining lamps would grow dim, but this is not the case. If we measure the difference or potential on the extreme terminals of the lamps we find it to be 200 volts; on the three burning lamps it is 50 volts each, while on the shunted coil it is 100 volts; so that the sum of the potentials of the three lamps and the coil is 250 volts, while the applied E. M, F. is but 200 volts.

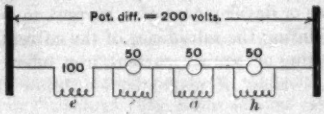

Fig. 10.

I think the explanation of this is as follows: During the first part of the rise of the E. M. F. wave, the shunt coil practically offers an infinite counter E. M. F., in comparison with which the resistance of the lamp may be neglected; when, however, the applied E. M. F. has attained a value of 100 volts, this counter E. M. F. is surmounted, because the core of the coil is saturated by the current flowing in the coil.

The lamps, therefore, receive the remaining 100 of the 200 volts applied, since the coil, being saturated, offers no additional counter effect. Now, after the wave of E. M. F. has declined to a value less than 100 volts, the stored magnetism in the core of the shunted coil begins to lose strength, and in so doing, develops an additional E. M. F., which, assisting the generator current, furnishes a current during the time the applied E. M. F. is of low, or zero, value, and by so doing keeps the average E. M. F. on the lamps constant.

It is necessary then, in working with alternate currents, to take into consideration the time retardation or lag of the current behind the E. M. F. We have seen that this lag is dependent on the resistance of the core, and on its degree of magnetization. I have found it especially necessary to make time corrections in work on alternate current motors, and in apparatus depending on the attraction or repulsion of magnets energized by alternate currents.

I have stated that there is no loss due to the periodic magnetization of iron cores by an alternating current. This is only true of a perfectly subdivided core. A solid core allows secondary currents to flow. Hence its storage capacity is lowered. In practice, the loss due to wasted currents in laminated cores can be kept as low as one per cent.

We may summarize the effects of the retardation of currents behind the E. M. F.'s in the induction coil as follows:

Retardation causes the counter E. M. F. developed to have counter values inversely as the quantity of current flowing in the coil.

Retardation causes the energy expended in magnetization during the increase or development of a current to be returned as current energy during the subsidence of the current.

To an alternating or similar current, iron offers true storage capacity for all values of magnetization below the saturation limit.

DISCUSSION.

THE PRESIDENT:—Discussion is now in order. Should there be any gentleman present who is not a member of the Institute, and who is wishful of taking part in the discussion we should be very glad to hear him.

MR. TOWNSEND WOLCOTT:—I would like to ask Mr. Stanley if he has ever observed an effect in reversing the magnetism of the cores other than that of the Foucault currents, that is, a sort of magnetic friction; the mere reversal of polarity, independent of any induced current, producing an amount of energy. I do not know how much it is. I know that some years ago a French physicist experimented with alternating currents, using a copper core in one case and an iron core in another. Had the heating effect been due to the Foucault currents, the copper would have

become much hotter than the iron, while in fact it did not get hot at all while the iron became hot; so there was an effect due to the simple change of polarity—a sort of friction:—it is analogous to friction. I would like to know how much effect that has in practice on the alternating systems.

MR. STANLEY:—In measuring the loss in an induction coil we have found a very slight unaccountable waste, so slight though, as to be almost immeasurable. It depends somewhat on the number of alternations that are driven through the coil. With about sixteen thousand alternations a minute the temperature of the coil, if it were placed in a calorimeter, would be indicated. The temperature of the calorimeter would indicate very nearly the amount of energy which was due to C^1 R, or the heating of the conductor itself. The iron of the core of the converter or the induction coil remains at a very low temperature indeed. Of

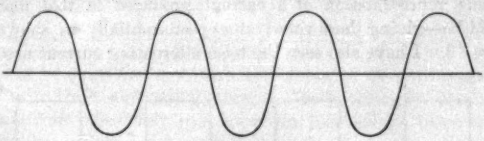

Fig. 11.

course there is a considerable radiation while in the air. Mr. Shallenberger in Pittsburgh has made several careful measurements and we are enabled to find that there is hardly any perceptible loss from magnetic friction. I can well see that with a very high degree of magnetization where the core was of a limited area in proportion to the number of ampère-turns surrounding it, that there might be a considerable waste due to magnetic friction or magnetic saturation, and with the induction coils as made for the distribution of electricity for lighting purposes this is very small indeed. I cannot tell you its extent, but it is very small.

MR. WOLCOTT:—The one per cent. you speak of would include that, as well as the Foucault current?

MR. STANLEY:—Yes, sir.

MR. HUBERT HOWSON:—In connection with this subject it occurred to me it would be of very great interest if we could have a precise definition of the term alternating current. In looking into this subject it seems to me the phrase has been used to des-

cribe different characters of currents, and possibly in the course of a very short time it may be found of interest to have a correct definition of this term. Perhaps I can explain my meaning by a diagram. As commonly used a graphic representation of the term alternating current, is I take it substantially what Mr. Stanley has given us in figure 7; but I have also found the term used to express a current which I should suppose was rather to be more correctly termed a reverse current. To give a graphic representation, we will say that figure 11 is what we ordinarily understand as an alternating current. Some of us know very probably that, in connection with the subject of distribution by means of transformers, it has been proposed to substitute for the alternating current generator, a generator which shall give a continuous current and which shall have in connection with it a commutator which shall reverse the current, and I take it that a graphic representation of a current produced in that manner would be—giving these time values—substantially as shown in figure 12. I have also seen the term alternating current used by

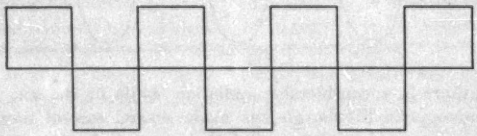

Fig. 12.

Mr. Stanley himself, I think, in connection with the description of one of his inventions—a very ingenious one. It was a system of distribution in which he proposed to use also a continuous current generator, and he proposed to use a transformer which should automatically convert that continuous current into what he termed an alternating current. The device he used was a transformer in which he had a core, two primary wires and one secondary wire. Of the two primary wires, one had a continuous current. The other primary wire had an automatic attachment, by which that continuous current was automatically broken and closed again. The result of that was, he said, that the core was magnetized and demagnetized very rapidly, and he called the current that was produced in the secondary an alternating current. It seemed to me that a graphic representation of that

would probably be as shown in figure 13. Now are we to use the term alternating current as applied to one or to all of these three things? That is the question that passes through my mind.

MR. STANLEY:—If I called the current produced, as Mr. Howson has suggested there in the last figure, an alternating current, I was certainly wrong and it is of very little value for the purposes of induction. The maximum electro-motive force is induced at a time when the current is changing most rapidly. Now the current does not change most rapidly between the points A and B, (fig. 5) but most rapidly from any point of any value, of any electromotive force whatever, to zero, and consequently we cannot get the same number of volts induced per foot of wire on the

Fig. 13.

converter or induction coil with this form of current that we get with a truly alternating current. It is necessary that the current should absolutely pass above the line and go below zero and rise above the zero line again, having plus and minus alternating values in order to get a maximum inductive effect. There will be residual magnetism no matter how successfully the apparatus is made to work. Necessarily any current of one sign—any plus current or any minus current,—must develop in any given time some residual magnetism in the iron, and consequently the secondary current cannot have as great value as it would have without that same amount of electromotive force, half above and half below the zero line.

MR. SCHUYLER S. WHEELER:—One point I think was passed over in reviewing that sketch on the board. I think the current drawn there as an induced current was an impossible one as far as an induction coil is concerned. If this represented the making of magnetism it would generate say a positive current like figure

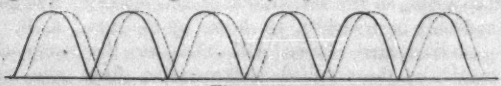

Figure 14.

14. Now, when that magnetism was broken or ceased it would generate a negative current. You cannot get impulses of posi-

tive current in an induction coil. I think it simply an impossible hypothesis.

MR. HOWSON :—My point was that the polarity of the coil in that case was never reversed. It was simply magnetized and demagnetized.

MR. WHEELER.—The demagnetizing would produce a negative current.

MR. HOWSON.—I would be very glad if Mr. Stanley would draw out the curve produced by the apparatus. If he has experimented sufficiently with it he may be able to do so.

MR. STANLEY.—Well, to begin with, we have a certain definite electromotive force applied to the apparatus as represented (Fig. 15). As that electromotive force is constant there is no in-

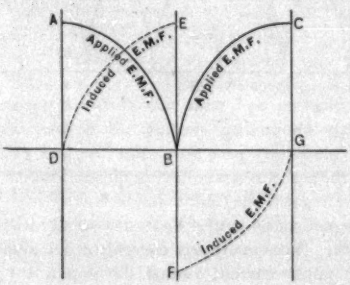

Fig. 13

duced current at that particular instant of time. Now if that electromotive force be varied, no matter whether it be open circuited or short circuited, or however it be—at this particular instant of time, there will be—at the instant of withdrawal, an induced electromotive force of a positive sign rising in opposition to the electromotive force proper, as shown by the line D. E. If we have an electromotive force of A. D. volts applied to a coil, on the withdrawal of this electromotive force, either suddenly or gradually, as shown by the curve A. B. Induced electromotive force will rise at the same time. This would be the applied electromotive force the other the induced electromotive force at that time. Now if the circuit be closed again, and the current developed as in the case B. C., the induced electromotive force at this time will be, I think, as

shown in the curve F. G.. During the development of the electromotive force or current the induced electromotive force will be of opposite signs. During the fall of the electromotive force it will be of the same sign. And I think you will find, if you plot it out, that the difference of equal value between applied and induced electromotive forces will be just one fourth of a complete period—that being called the period of complete alternation, if it were an alternation apart.

DR. P. H. VANDER WEYDE:—To properly understand those currents we must draw two entirely different lines; one curve representing the rise and fall of the electromotive force; another curve representing the positive and negative of the induced current. When the primary current is only rising and falling, it is all of one sign—it is either all positive or all negative. It comes to the neutral line and then rises. Now, we can, if we only interrupt the current, when we have a current of the same sign—the primary (the secondary is always of different signs; the secondary is always positive and negative whether the primary is or is not)—but if we cause the primary to alternate too, we increase the electromotive force of the induced current. We get, by the fall of the current in the primary wire—we get the current in the same direction in the secondary wire; but if in place of merely interrupting the current, we change the sign, that secondary current is increased—by the primary current in opposite direction. I made a series of experiments several years ago, and I was induced to prosecute them. They were very encouraging and very interesting. I had constructed a relay with two coils—a primary coil to receive and transmit the current, through a secondary coil over another circuit. The first experiments gave me very curious results and I have extensively continued it and finally come to the construction of several forms of transformers and very peculiar forms too. I found at last that it was of the utmost importance, if we wished all the benefit of our primary current, to close the magnetic circuit, as I call it—to put pole-pieces to the cores or connect the cores. If we put a pole-piece to the cores we get, at the first break of the contact of the primary current, a very strong secondary current; but it is only at the first break of the contact. The second break is weaker—much weaker, and I found that it lost considerable magnetism. When we open the armature again, then we get the secondary current.

What was to be the remedy of that? I found soon that the only remedy was to be the reversion. We cannot repeatedly break the armature contact, but when we reverse we have the full effect—not only that—but we have the double effect of the reversal of the polarity of the core. When I found that fact I made a series of experiments, always with measurements with the volt-meter to see how many degrees of difference there were. I had constructed a volt-meter, which I arranged so that ten degrees represented a volt. At the same time there was an ammeter connected with it which was constructed similarly. The first experiments were to remove the core and substitute a solid piece of iron which had more than double the weight of the original core. I elongated the solid core. I put in a 24 inch core. Then I commenced again with wires and I took a piece of wire for a core 6 inches long and I took a piece of wire 24 inches long and I found that one piece of wire gave quite a deviation and

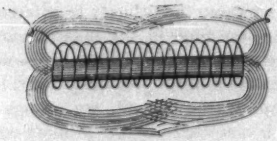

Fig. 15 A.

half a dozen pieces of wire gave more deviation than the whole bunch of 280 wires which had formerly filled it. Among other interesting experiments was the following, shown in figure 15 A I used 280 soft iron wires for the core and then I bent them around. I took half of these wires and bent them around one way; then I took the other half and bent them over on the opposite side and in that way surrounded the whole and interlaced the wires well. Then I had a coil on which at the first contact we had a very strong induced current about four times the intensity which you could obtain otherwise. But then I found the necessity of reversing. When I reversed the current then I got about four times the intensity of the current. I have such a coil with me, which I would be glad to exhibit to the gentlemen present.

MR. GEO. B. PRESCOTT, JR:—I would suggest that Mr. Stanley get the date of the invention from Dr. Vander Weyde, as that is the induction coil now manufactured by the United States Electric Lighting Company.

MR. WOLCOTT.—As the electromotive force falls off as Mr. Stanley stated, it would generate electromotive force of the same kind in the same direction in the secondary. I distinguish here between electromotive force and current. Of course the current would not follow on account of self-induction—would not follow electromotive force, just as he has shown in some of these diagrams here. If that fell off it would make a negative electromotive force in the secondary, and as it rose again the direction

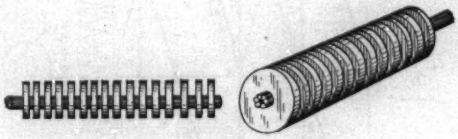

Fig. 16.

of the primary current is reversed and also the direction of the secondary electromotive force with respect to the primary. But of course if the wires were a complete circuit so that we could have a current, the current would vary very much from that. As I take it, that is very similar to the case of a Rhumkorff coil in which the current is exactly alternated. The conditions can be so fixed that the current in closing the coil is very small—the electromotive force is low at least. In no case is it anything like the electromotive force of breaking the circuit of a Rhumkorff coil.

MR. STANLEY.—With your permission, I will endeavor to sift out this subject a little bit more. As I understand it, the effect of joining the magnetic circuit around the primary and secondary induction coil is practically to reduce the wire, if I remember correctly, to about one-sixth. In experimenting with coils, to begin with, I took Faraday's ring and wound a coil on either side. The best coil I have ever seen consisted of a bundle of straight wires on which was threaded a lot of iron washers (figure 16.) This

has the highest counter induction per unit of length of any coil I have ever seen. In the Westinghouse Company's system we get about two volts per foot of wire. This coil gave, if I remember correctly, about a volt to four inches. But it was impracticable to construct, as they could not make them fast enough. As I understand it the curves of electromotive force induced from an alternating current are these, Fig. 5. *A*, *B*, *C*, *D*, *E*, is a complete period of the curve of the primary or applied electromotive force. Now the induced electromotive force will be maximum at the time when the inductive effect of this primary current is a maximum; and the inductive effect of the primary current is a

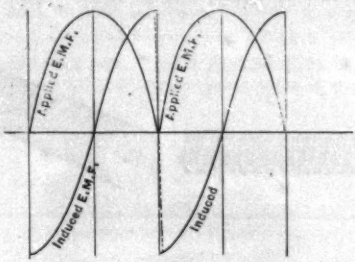

Fig. 17.

maximum when it changes from zero to any larger value. Consequently, the electromotive force of the induced current shown in the lower curve, figure 5, will be a maximum at this time; and it will be a minimum when the inductive effect of the primary is a minnium, and that will be when the rate of change of the primary is the least, viz., at the crest of the primary wave *B* and *D*, we find that the same values of applied and counter electromotive force are just one-fourth of the whole period of phase of the current. That is with an alternating current. In the direct current we never can have as great an electromotive force induced in the secondary circuit because our primary circuit never passes the zero line. The curve of induced electromotive force in the case of a broken, direct or interrupted direct current I think is this, Fig. 17. As will be seen, the induced current will be of negative sign, while the positive current is going to

maximum; and the induced current will be of positive sign, while the applied current is falling from the maximum.

MR. WOLCOTT.—How do you get from the positive to the negative there?

MR. STANLEY.—The rate of change at the break is enormously rapid.

MR. WOLCOTT.—It is infinite according to that.

MR. STANLEY.—It is almost infinite. If the severance of a contact requires no time whatever then it would be a straight line; if not it would be a little inclined.

Perhaps it might be interesting to illustrate the applications

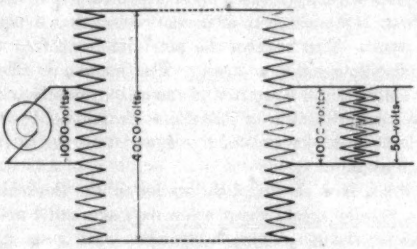

Fig. 18.

of induction coils for covering long-distance distribution. It is well known that the cost of a conductor varies inversely as the square of the electromotive force. The cost of the conductor for transmitting a given amount of energy will be, for 100 volts E. M. F., we will say, x dollars, while for a 200 volts pressure the cost will be $\frac{x}{4}$ dollars. Therefore, the economy of the alternating system over others is directly as the square of the ratios of their electromotive forces. But in order to cover enormous distances and to make the system as broad as possible, I devised another plan which may or may not be new. We are to apply it in Berkshire County, Mass., to distribute from a station over 6 miles of territory with a loss of 2 per cent. We have 100 horse-power to distribute and the potential of distribution is to be 4,000 volts. Our alternating current dynamo is of 1,000 volts. In

order to get the electromotive force up to 4,000 volts we simply wind one coil of wire and attach our dynamo to intermediate terminals of that wire, distant apart one-fourth of the entire length, as shown in figure 18. That is, the length included between the terminals is one-fourth of the whole length of wires wound on the coil. There is no secondary circuit whatever. Of course there is an induced electromotive force upon every turn of wire on that core of so many volts per turn. We apply our electromotive force of 1,000 volts at those points in order to get 4,000 volts between the outside terminals. When we carry our current at this enormous potential over to the place where we wish to distribute we simply attach another self-induction coil similar to the first. On one-fourth of its entire length we tap out another circuit. That reduces the potential from four thousand volts to one thousand volts again. The maximum efficiency of an auto-converter, or converter of one coil, evidently is found in the case where the ratio of reduction is from 1 to 2, or 2 to 1. If you have it in the ratio of 1 to 4, or 1 to 6, the saving is not nearly as great.

Mr. Prescott.—I visited the station in the Berkshire Hills, that Mr. Stanley speaks about, a few days ago, and I noticed that they had for the generators one omnibus wire running around the station such as are used in the Edison stations. But this omnibus wire was split in two, and each generator worked into its own circuit. I asked the attendant why the omnibus wire was not connected across and he said that if they connected it across they were likely to burn out their armatures. I would like to ask Mr. Stanley if that is so?

Mr. Stanley:—That is so, through an oversight in the construction of the dynamos in the early stage of the business. We all have to learn some things; and the reason why it has been difficult to multiple-arc alternating dynamos is, that the phases have not been exactly the same. We made our dynamo pole pieces of cast-iron. Those cast-iron pole pieces did not measure to a thousandth of an inch the same width, and consequently the two phases of current, which ought to have coincided, did not coincide exactly, simply because of faulty construction. By tooling off and cutting the width of the pole pieces to an exact measurement, there is not the slightest difficulty in multiple-arc-ing two, three or four alternating dynamos. I think a new feature in alternating currents, perhaps not well known to every one here,

is the remarkable self-regulation of the alternating current machine. I cannot speak of it fully, because I have had very little to do with it. Another man is responsible for the beautiful work he has succeeded in getting. In Pittsburgh, a few days ago, I saw a 2,500-light dynamo run by a 250 horse-power engine, and 2,150 lights thrown by a single switch. The rise in electromotive force was one volt. I submit, that in the present state of the art, it is impossible to construct a direct current machine which shall have anything like the self-regulation these alternating machines exhibit. The resistance at the commutator of a direct current machine would cause a greater variation of potential than was manifested in this machine I speak of. In the induction system we start out with an alternating current machine, in which we pretend to have at least a maximum loss of two volts in electromotive force in the dynamo with the proper regulation necessary to any machine. Towns are wired, at least I know of two pole lines which are wired, for one per cent loss of electromotive force, distributing electricity generally over an area of about a mile radius. The actual loss in the mains is one per cent. In the induction coil, at full load, there is another loss of two per cent.

MR. MAILLOUX:—I was expecting that somebody would refer to one of the features mentioned by Mr. Stanley this evening, which is to me one of the most interesting, from the theoretical as well as from the practical standpoint, inasmuch as it leads to a score of applications. It is that system in which four lamps, *a*, *b*, *c*, *d*, were connected across the terminals of a constant potential alternating circuit; and in which this difference of potential for a particular lamp cut out was taken up by the self-induction coil as *e*, figure 10. Now I would like to ask Mr. Stanley whether the object of using that induction coil was merely to balance the other lamps, or whether it was expected that any energy would be saved by its use; in other words, whether the two lamps running with the circuit continued through the self-induction coil would require less energy than would the four lamps.

MR. STANLEY:—The connection of the lamps in series in that way was for a street-lighting system. In order to distribute lamps economically for street-lighting purposes the plan adopted by Mr. Shallenberger was brought out. The shunted coil on the extinguishment of any one lamp prevents the rest of

the lamps going out. For instance, there would be twenty lamps attached to a 1,000-volt circuit, each lamp of 50 volts. Now all those twenty lamps may go out, or nineteen go out and the remaining lamp would be at approximate candle power; and yet the sum of the separate electromotive forces, measured by a volt-meter around the lamps and coils, is far in excess of the electromotive force that is applied to the outside terminals of the series.

For instance, there are four lamps connected in series. There was a lamp connected at *a* Fig. 9. That lamp is extinguished and in place of it there is a self induction coil *e*, Fig. 10. This series is connected to a circuit whose E. M. F. is two hundred volts; a volt-meter connected to each one of these lamps will show for the lamps *b*, *c*, *d*, 50 volts each, and for the self induction coil, 100 volts. Now the sum of the interior electromotive forces here is two hundred and fifty volts. The same volt-meter will show an electromotive force of two hundred volts on the outside terminals. That is, the sum of the interior electromotive forces is greater than the applied electromotive force. I think that can only be explained by the retardation of the current producing the average electromotive force.

MR. PRESCOTT:—In regard to the point that Mr. Stanley kindly replied to a moment ago, I would say that it is of course well understood that if the time phases of any number of alternating current machines are identical there is nothing to prevent their being worked in multiple-arc. Now the question to my mind was whether there is any practical difficulty in getting those time phases the same. Of course that includes not simply the electrical and mechanical construction of the machine; it requires them to be identical in that respect. Now I have seen only two Westinghouse stations, and in both of them, each dynamo had a separate engine and in both cases the machines supplied separate circuits. Is there any case of any plant now in operation where a number of machines are successfully used in multiple arc?

MR. STANLEY:—I think at Denver, Col., a station of five thousand lights is run with dynamos in multiple-arc, although I am not sure. The Pittsburgh station has been run in multiple-arc. Our policy is not to run in multiple arc. We prefer not to. There is no choice in the matter excepting only that of simple expediency. We construct the station switch-board so as to connect any circuit leading from the station to any dynamo

without causing a flicker in the lights, and thus give the dynamo a definite load that you can read on the amperemeters. That seems to us to be a very satisfactory way to run. As the evening grows later lights are cut off, the circuits are transferred from a number of dynamos to perhaps a smaller number, and eventually down to one dynamo which runs all night.

The subject of multiple-arcing of the dynamos comes so near the question of running alternate current motors that it is the same question practically, and I feel, perhaps, justified in explaining a little phenomenon in that. If you take two alternating current dynamos and couple them together, and start them up, one dynamo will fall into sychronism with the other. In order to have an alternating current motor, it is necessary to have a direct current through the field and an alternating current through the armature. In order to get a direct current through

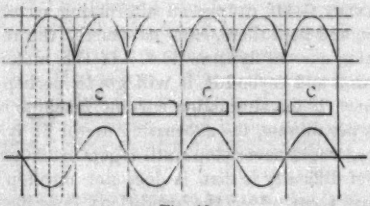

Fig. 19.

the field, you have got to have a commutator, which will redirect the field current. This current in the field will rise from zero to a maximum value and fall again to zero value, but the armature currents will be above and below the zero value, as shown in Fig. 19. Now, notice, that at the time marked by the full vertical lines, there is no current flowing through the field, and there is no current flowing through the armature. If, then, we have an alternating current motor which is running with the exact speed and in conformity with the number of alternations of the dynamo which is applied to it, and have the phases of the two currents in exact synchronism, that is, with equal phases coming together at the same times, we will have absolutely no current in the field while there is no current in the armature of the motor. Now the commutation of the field may be outlined as shown where *C C C* indicate the commutator segments. There has been, until the motor arrived at synchronism, commutation

at different points in the phases as at the dotted vertical lines. But when the motor runs at exactly the same speed as the alternating dynamo, there is no force then at work keeping the motor going. In other words, you can run an alternating current motor up to speed, but the minute it goes into absolute synchronism it will fall off again, and the consequence is that the alternating current motor will see-saw. There will be no power to continue its motion. Its speed will fall, and it will drop down to a lower number of alternations, but will rise up again.

MR. PRESCOTT:—What is the effect if you have just enough work on to keep the speed down?

MR. STANLEY:—Then it will never rise to synchronism.

MR. RICE:—I would like to ask Mr. Stanley in reference to his last statement as to the motor, what percentage is the variation in speed?

MR. STANLEY:—Of course an alternating current motor in synchronism and kept there, runs at exactly the same speed as the alternating current dynamo does. If the motor, is impelled to synchronism and beyond it, it will go to perhaps double the synchronism. If the alternating current machine is run 16,000 alternations per minute, the alternating motor if it goes beyond that number, would never stop until it gets to 32,000 alternations. But the chief difficulty is that it does not develop any counter electromotive force under the conditions described, because it cannot develop a counter potential unless it has at all times a constant field charge. As the current falls to zero, of course, it cannot develop any counter electromotive force at that time. An alternating current motor has no efficiency of any consequence until it arrives at synchronism and becomes practically a dynamo running in opposition to the dynamo applied to it, at which time it has an enormously high efficiency with the most perfect self-regulation.

MR. RICE:—I hardly understand what Mr. Stanley means, in view of some experiments we tried recently. We had a self-exciting dynamo, and ran it in multiple arc with another self-exciting dynamo, and then threw the belt off. The current from the generator proper passed from the armature of the motor. We did not find any variation to speak of, and it ran perfectly in synchronism. It was a generator capable of giving out about twenty-five thousand watts. I then loaded it until the motor was giving out in the neighborhood of fifty thousand or sixty thousand watts

without any change whatever in speed or any tendency to variation.

MR. STANLEY :—It had an alternating field in which the magnization periodically fell to zero. But in the dynamo the gentleman speaks of I understand the magnetization of the field was always the same. Consequently it was a true alternating current motor.

MR. RICE :—I do not see exactly how that meets the question, because the field of the motor was charged by itself, therefore it was falling from zero to zero again.

MR. STANLEY :—The field of the motor was charged by a current developed by the motor itself on its own armature.

MR. RICE :—Yes, sir.

MR. STANLEY:—And the phase of the current did not coincide with the phase of the applied electromotive force.

MR. RICE :—If I understand you, for a certain period of time a motor running is exciting its own field. There was no opposition to the primary current from the generator.

MR. STANLEY:—That is true. When the current in the field is zero, and the field charge is zero, then there is no electromotive force producible of course. But if the field charge is constant then it will develop a counter electromotive force and become a true motor.

MR. RICE :—I understood you to say that the field would fall to zero from the self-exciting motor.

THE PRESIDENT :—I would like to ask Mr. Rice if he is at liberty to give us a little information on the point of sychronism?

MR. RICE :—All that I can say in regard to that is that we have tried multiple-arc-ing dynamos. We have run dynamos together for a period of twenty hours continuously and the loads seemed to be very equally divided, when the speed was kept uniform. We have also experimented with motors and found no difficulty in that direction.

I was very much interested in the system which Mr. Stanley attributes to Mr. Shallenberger. I think it is only just to Prof. Elihu Thomson to say that that system was patented by him three or four years ago. He used almost identically that same arrangement which consisted of placing a self-inductive coil in place of a lamp, so adjusted that it would take just the current of the lamp. I do not know that that was the first time it was done, but so far as I know it was.

In reference to Figure 4, I do not know that I correctly understand Mr. Stanley's explanation of it. The diagram, I understand Mr. Stanley to say, applied to a coil in which there were iron cores. Is that true?

MR. STANLEY:—Yes, sir.

MR. RICE: And you say that the self-induction follows exactly the primary. Now it seem to me that coils with iron or without iron are the same excepting a difference in degree; there is no difference in kind. In that case it seems to me there would be a slight shifting.

MR. STANLEY:—The difference in ratio is one to many thousands, and it being so small I thought it was not worth while expressing it.

MR. WHEELER:—I would like to ask Mr. Stanley whether there are any losses on the line wire other than that due to resistance—whether there is any current dissipated by retardation, self-induction, or anything of that sort?

MR. STANLEY:—I was perhaps the worst frightened of any man who ever stood on solid ground when I read Prof. Hughes's ecture on self-induction. But the effect of self-induction which he described, and the measurements on which it was based, were made with a broken direct current. With the system that we use we have not been able to find any variation from the true Ohm's law, and all our wiring details are based on the assumption that the resistance is the ohmic resistance of the copper only. In the case where the wire goes around an iron core it is not necessary that there should be a loss of electromotive force. The electromotive force is merely retarded for a moment, and as soon as it has fallen to a value below that of the charged magnetism, the stored electromotive force is all returned to the circuit. I think there is nothing so generally misunderstood as the loss of electromotive force on iron cores.

MR. WHEELER:—It is a case of magnetic storage.

MR. MAILLOUX:—I do not think Mr. Stanley exactly answered my question, and the remarks made bring us back to it again. The question is whether in that circuit that he speaks of in which an induction coil is substituted for a lamp, whether the loss of energy, in other words, the expenditure of energy, across that line is different in the second case from what it would be before that induction coil had been substituted. If, as Mr. Stanley argues, the effect of self-induction is simply to retard the electro-

motive force, then evidently we still have electromotive force there, and if it does not absorb electromotive force or cause loss, then we should take less energy than would be accounted for by that which would be absorbed in the three lamps, plus that absorbed in the ohmic resistance, as he calls it, of the self-induction coil. For we must remember that the amount of energy required at the terminals of the induction coil is not as much as would be represented by $C^2 R$. It is $C R$, plus a certain quantity which represents the work done in the induction coil in overcoming the counter-electromotive force of the coil. Now, then, it is interesting for us to know whether in that case the expenditure of energy was the same whether the induction coil was on, or whether the four lamps were burning at one time. I incline to the opinion that it must have been the same, and that consequently there must have been a certain amount of work which was absorbed and dissipated by the self-induction coil.

MR. STANLEY:—The energy on the lamp is exactly the same. If it were not the lamps would grow brighter. The potential on them is constant. The current going through them remains constant or they would not be of the same brilliancy. The self-induction coil does waste some energy, but it has the effect of storing energy for a brief interval of time and then returning it upon the circuit. As to the invention of the self-induction coil for this purpose, I have the very highest regard for Professor Thomson and always had, but if I remember correctly, the patent that Mr. Rice refers to is not for this purpose. It is for cutting in a coil. This is a very different invention. This is a coil always in circuit to do this work, while the coil Professor Thomson devised is cut into the circuit.

MR. MAILLOUX.—I would like to state then that my conviction appears to be upheld by Mr. Stanley, that, the energy being the same, this induction coil represents nothing more than resistance. It takes up a certain amount of energy which a certain idle resistance would clearly absorb. If we were to replace that self induction coil by another one having no self-induction, but a larger resistance, so that the circuit going into that resistance would absorb the same number of watts, then we would evidently have the same energy absorbed as we have by that induction coil. So that I do not see the induction coil in question does anything more than to replace a lamp that is put into that circuit. The case is exactly analogous to that of an electric motor that would

be placed in circuit. The energy absorbed by an electric motor is the difference of potential into the current.

It is just exactly the same case in that induction coil. But in the case of the electric motor, as in the case of the self-induction coil that energy can be divided into two quantities, one of which is the $C^2 R$, the other of which is the product of the current into the counter-electromotive force. Now at first you might think that in using a motor as a resistance, the counter-electromotive force of the motor would act, so to speak, statically, upon the total electromotive force and reduce the total expenditure of energy in the circuit; but as long as the current is not reduced it can be readily seen that there is no reduction of the energy expended, because you simply have a certain amount of work which is absorbed electrically, and which that motor does either in useless friction, or in useful work, in connection with a Prony brake or some other piece of machinery. Therefore, in addition to $C^2 R$ representing the necessary loss,—we have another quantity which is the product of the current into the counter-electromotive force exerted by the secondary coil, whatever that may be. Now what I would like to know, if possible, is how that can become dissipated. It certainly seems reasonable that if there is extra energy dissipated there that the coil ought to become a great deal warmer than if it were not doing any such work.

MR. WETZLER.—It occurs to me that perhaps this phenomenon might be due to an error, or a peculiarity, of the measuring instrument employed. Mr. Stanley said that he employed a Cardew voltmeter. I would like to know wether he ever applied the electro-dynamometer for that purpose.

MR. STANLEY.—The electro-dynamometer is a very unfortunate instrument to use with an alternating current, as its reading is changed by a slight fluctuation in the alternations. The Cardew voltmeter, which is dependent on the amount of heat produced, is entirely independent of the alternations. Perhaps I can explain that. The coil is acting exactly as a dynamo would act in series and it chokes down the current in direct proportion as the resistance in this part of the circuit is raised. The average electromotive force at the terminals of the coil, however, is greater then would seem to be warranted by Ohm's law.

MR. HOWELL.—Mr. Stanley said that inasmuch as the current was constant, as shown by the lamps; that is, the current in three lamps was the sam as the current in four and that the electromo-

tive force acting on the circuit was also constant, that the energy was constant in the circuit. I would infer then that $C\ E$ is the measure of energy in the alternating current. Is that a correct conclusion?

Mr. Stanley.—No, sir; that was a slip of the tongue perhaps on my part; but it is a most unreliable quantity. The energy of three is the same as the energy on the three lamps before. I think in reality there is very little waste of energy. But there is an apparent amount of energy wasted there—that is $C\ E$ of the coil. This is apparently as much as the energy expended on the lamp.

Mr. Howell.—I think that that diagram is a very good illustration of the fact that $C\ E$ is not a measure of the energy in an alternating circuit, because you have only a value for C there, and the value of the energy in that circuit would be $C \times 200$. Now that is the sum of the energies in three lamps and the coil, and in each lamp it would be $C \times 50$, and in the other it would be $C \times 100$; so that the sum of these energies is not the same as the sum of the whole circuit computed the other way, which shows that $C\ E$ is not the measure of the energy in the circuit.

I would like Mr. Stanley to demonstrate why the current in the secondary increases, or why an increase of current in the secondary increases the current in the primary.

Mr. Stanley.—I think that it is very easy to understand from the diagram, Fig. 7, of the counter-electromotive force, providing no current is flowing through the coil. The secondary electromotive force will of itself induce another electromotive force and so we might go on inducing forever electromotive force. We cannot merely transform energy once; we can transform it a thousand times. Now the secondary electromotive force will develop a counter-electromotive force on the primary circuit, and that will be still one-quarter of a period later. Notice that I have drawn these curves directly opposite. It exactly opposes the primary electromotive force at the same instant of time. Now, when the current is abstracted from the coil, this is no longer the position of the secondary electromotive force; it is shifted on. Consequently, the counter-electromotive force no longer opposes the primary electromotive force at the maximum time of the primary electromotive force, and consequently its value as a counter or opposing E. M. F. is very much lessened. You have asked me a difficult question.

MR. WHEELER:—While of course Mr. Stanley's explanation is exactly correct, I think that Mr. Howell's question could be answered in popular language by saying that the drawing of current from the secondary coil reacts on the electromotive force. In other words, drawing a current through the secondary coil cuts down the maximum and makes it harder for the primary circuit to magnetize the iron of the converter. I would like to return to the three lamps and the induction coil, because I wish to ask this question:—Mr. Stanley stated, (see Fig. 9) if this was connected into a circuit of two hundred volts, e would measure one hundred volts and that the lamps f, g, and h, would each measure 50 volts, making a total of 250. Now I would like to ask Mr. Stanley what he would get if he measured the potential between the conductor and the right-hand terminal of the lamp b.

MR. STANLEY:—I never have tried it.

MR. WHEELER:—I think that would be an interesting thing to find out; because there are 50 volts in a corner there, and I would like to know just where they are to be found.

MR. MAILLOUX:—I have been in the habit of reasoning in relation to secondary currents by analogy to the electric motor, and I consider it a perfectly logical and applicable method. In this case, as is well known, the electrical energy applied is the sum of two quantities, one of which is the familiar $C^2 R$, or energy expended in heating the motor, and the other (ϵC), the energy available for conversion or the product of the counter-electromotive force into the current. I will adopt the direct current system of reasoning because it is one which we all understand.

If, as Mr. Stanley says, there is but little difference in the amount of energy when the induction coil replaced the lamp, then it is evident that some of the energy must have gone somewhere.

The energy absorbed in the four lamps (Fig. 9) is evidently the square of the current that is passing through them, into the resistance, or $(C^2 R) = C^2 (r + r + r + r) = 4 C^2 r$. To pass this current through the lamps a certain difference of potentials is necessary at their terminals; that is to say at the leads (+ −). In the continuous current system, we could therefore express in another way the energy absorbed in the lamps, and I have no doubt we could do so in an alternating system, if we can get the mean E. M. F. as is done with the Cardew voltmeter. We would

then have for the expression of this energy, the product of the difference of potentials, into the current, $(C\,E)$; consequently we can say:

$$C^2\,R - 4\,C^2\,r - C\,E$$
$$- C\,(e + e + e + e)$$
$$- 4\,C\,e.$$

Now, when we cut off one lamp, and put a coil in its place, we still have the same potential difference at the terminals,—that is evident. Since the other three lamps remain of the same brightness, they each have the same energy $(C\,e)$ given to them as before. Observation showed moreover, that the potential difference of each lamp remained as before (e); hence, the current (C) must be the same. Consequently the energy sent into this branch must be the same as before, and the energy given to the coil must also be the same as that taken up by the lamp it replaced;

$$4\,C^2\,r - 3\,C^2\,r = C^2\,r$$

or to express it more conveniently,

$$4\,C\,e - 3\,C\,e = C\,e,$$

the latter term being the same as the energy given to one lamp.

In the case of the lamp all of this energy was absorbed in heating resistance, but with a self-induction coil this cannot be so, for the resistance is very small. We must therefore, decompose the product $(C\,e)$ into two other quantities. We now have a counter E. M. F. to deal with, produced by the self-induction coil, just as in an electric motor, and which I may express by the same symbol (ε). Taking r' to indicate the much smaller resistance of the coil, we have

$$Ce = C^2\,r' + \varepsilon C.$$

This is the energy given to the coil and as we see, only a part of it $(C^2\,r')$ has the term resistance (r') in its expression and this portion disappears as heat in the coil itself *The other portion* $(\varepsilon\ C)$ *does not involve resistance and consequently does not disappear as heat in the coil.* It represents energy available for conversion, just exactly as it does in the case of a continuous current motor. This erratic energy $(\varepsilon\ C)$ is the very energy which I wanted to send Mr. Stanley looking for. It is evident that it must have been taken up by or restored to the circuit. It occurred to me that it may have gone in some of the other branches. There are a lot of those lamps connected together. As I understand Mr. Stanley to say; this is a multiple-arc connection.

MR. STANLEY:—All in series—every one of them.

MR. MAILLOUX:—It would not make any difference for we have in both cases a certain time in which there is no current in the circuit, during which our induction coil will be charged. I am satisfied that the product (ε U), must go somewhere and it is going to do work either by heating the coil or wire, or else it is going to do work by producing E. M. F. in the circuit. Now the electromotive force which is due to this product, (which I designate by ε, as being a part of the energy that is being taken up by the coil), or in other words the counter-electromotive force—may act by producing energy at a time when there is no current, for, as we know, the wave of current in this branch would necessarily lag behind that in the others. Consequently, there would be a time when the original impulses passing through the circuit would reach zero, while this had not reached zero. I would like to ask Mr. Stanley whether those impulses which would be produced there, and having this reaction and this retardation—would not produce an impulse of their own through the circuit, which would account for the energy that must be dissipated somewhere or other.

MR. STANLEY:—I do not know where it goes. I presume the lag certainly does throw back the electromotive force to the rest of the circuit. It does not throw it out into the air. You wind a wire around a piece of iron, submit it to an alternating current; for all values below saturation it has this counter-electromotive force. That counter-electromotive force does not waste any energy in overcoming it. It simply reduces the amount of potential which is absolutely applied, to C^2 R, but when the core is saturated in the coil, then the coil acts like a straight line. A very pretty illustration of the way the connection of the Gaulard and Gibbs apparatus in series—they connect converters in series and hitch them to a dynamo in which a definite quantity of current was always forced through the primary circuit. That amount of current was enough to nearly saturate the cores of the coils in order to obtain self-regulation. But if, through any misadventure the electromotive force raised a small percentage, the coils no longer opposed any counter-electromotive force and the current would follow through the coils at a most terrible rate, destroying the dynamo and producing all kinds of troubles. In this coil in the series arranged here it seems to me that this coil merely reduces the electromotive force and does not waste any energy as it simply passes the electromotive force that the dynamo applies.

MR. MAILLOUX :—I do not think that it can be considered as acting merely to reduce. It is quite certain to my mind that it must act as a spring would when you compress it and when you release it, as you do at every alternation. That spring must return energy somewhere. A part of that energy is due to friction of the molecules in heating, but there is also a part which is available for work and that part must either return energy into the circuit or else it must go out into the air. I cannot for a moment entertain the idea that the induction coil in that place would simply act to reduce electromotive force, and I think if anybody stops to study the subject they will arrive at the same conclusion. I do not think it can be demonstrated either mathematically or in any other way that the induction coil acts in that manner.

MR. WHEELER :—We were told a little while ago that there was no loss from retardation of induction with an alternating current. I would like to ask Mr. Stanley what the difference is between sending an alternating current over an electric light wire or an ocean cable.

MR. STANLEY :—I am not very familiar with ocean cables. But I presume the character of the current explains the whole difference. The character of the current bears a very important relation to the resistance which it possesses. If you have two circuits, ocean cable for one and ordinary overhead wire for another, the same number of alternations will not do for each; because, as you might say, the magnetic lag of the ocean cable is very much greater than it is from a short electric light wire. If you apply a proper alternation to an ocean cable, I should certainly expect to find no real loss in transmitting it. If, on the other hand, you apply it to an over-head circuit, in alternations so rapid that the circuit cannot receive it without impeding the on-coming impulses, you cannot transmit the alternating current over the over-head circuit without a loss.

DR. VANDER WEYDE :—Could you charge a Leyden jar with an alternating current?

MR. STANLEY :—No, sir; I do not think so.

MR. WETZLER :—It occurs to me to bring forward the point, namely: What we are measuring when we apply an instrument to an alternating current circuit? This curve Figure 20, represents the rise and fall of potential. We are measuring under ordinary circumstances, I should say the distance *c d*. May it not be possible that under certain conditions, we may be measur-

ing, say, the difference between y and y'; this is a greater difference of potential, indicated as the electromotive force between the terminals of the alternating current circuit, depending on the conditions under which the instrument is applied, or the organization of the circuits themselves.

MR. PRESCOTT:—As it is a well known fact that alternating currents do not follow Ohm's law, and nobody knows what law they do follow, why might we not expect the fact that the one hundred may be dealing with entirely different units than the other fifty—we do not know anything about it in fact.

THE PRESIDENT:—I presume that there is no further discussion; and I think that I may safely say that of all discussions we have had before the Institute, we have had none more valuable, none more suggestive; and I think we shall all appreciate the fact that it has been of material service to us to have been able to be here

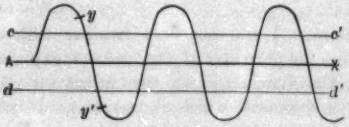

Fig. 20.

this evening and take part in the discussion, or listen to what has been said.

I would like to announce that our next meeting will be held on December 20th, a special meeting, when a paper will be read by Mr. Arthur Steuart, the legal counsel of the Electric Light Association, on Reforms in the Patent Law. I may say that this matter of patent reform is one in which it is advisable not to move hastily, and it is a question that ought to receive the largest ventilation possible. In that view it is extremely desirable that the attendance should be as large as possible on the evening in question.

On motion the meeting adjourned.

The following letter, supplementing the foregoing discussion, has been received from Mr. Rice.

Lynn, Mass., Dec. 7th, 1887.

T. C. Martin, Pres't.

DEAR SIR:—I regret greatly that it was necessary for me to leave before the interesting discussion on the subject of alternating currents was concluded, as I was obliged to take the train for Lynn.

I was anxious to state in answer to Mr. Stanley that I had no desire to disparage the work of Mr. Shallenberger, as I have the highest regard for his genius as an inventor and for his ability as an electrician.

The point which I desired to emphasize was that Prof. Thomson was the first person to proportionate a coil so as to act as a substitute for a lamp, and also the first to publish the same, in the patent referred to. It is true that in Mr. Shallenberger's arrangement the lamp is shunted around the reactive coil, while Prof. Thomson shows the reactive coil designed to be switched in place of the lamp, this latter method being preferable on the ground of economy, as when the lamp is shunted around the coil a certain percentage of the energy is wasted by the coil.

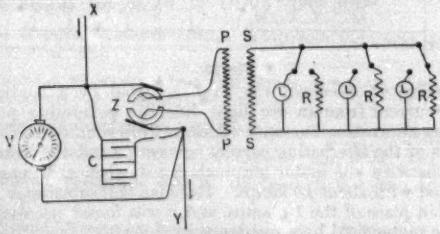

Fig. 21.

I was astonished to hear Mr. Stanley make the statement that the energy used was the same in the two cases of four lamps, of 50 volts each placed in series across alternating mains, with a difference of potential of 200 volts, and that of a reactive coil substituted for one of the lamps. It may be interesting to mention an experiment which Prof. Thomson made in my presence several years ago, and which demonstrates very beautifully the fact that a reactive coil can be substituted in place of a lamp with but very little absorption of energy. A constant current was reversed in direction by means of a commutator through the primary circuit of an induction coil, and the secondary circuit of the coil was used to supply about six incandescent lamps, Fig. 21. Properly proportioned reactive coils were arranged to be substituted for

the lamps. It was found that by shunting the terminals of the primary circuit by means of a volt-meter placed beyond the commutator that the potential was greater when the lamps were in action than when the reactive coil substitutes were put in place of the lamps. As the current was constant, about 10 amperes, this demonstrated that the coils were absorbing but little energy. It was found that as the coils were substituted in place of the lamps that the brilliancy of the remaining lamps did not change. This was true even after five of the lamps had been replaced by reactive coils, the remaining lamp having the same brilliancy as before.

The same fact is also demonstrated by another experiment which was tried about the same time, (Fig. 22.) In this case a

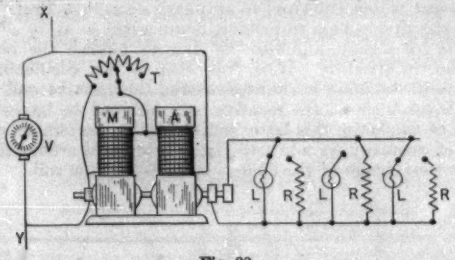

Fig. 22.

motor generator, so-called, was used, actuated by a continuous constant current from an arc light line, the generating portion producing alternating currents. Lamps were shunted across the terminals of the alternating current generator and the potential existing between the motor terminals noted when the generator was loaded with about 10 lamps. Reactive coil substitutes were now put in place of the 10 lamps, and it was found necessary to shunt the motor field by a resistance in order to reduce the potential between the motor armature terminals, otherwise its speed would rapidly increase as the reactive coils were substituted in place of the lamps. This indicated that less electric energy was required by the motor when reactive coil substitutes were used in place of lamps.

It was found that, as in the preceding case, the brilliancy of one lamp when running in connection with nine reactive coil substitutes was the same as when running with the other nine lamps.

Yours very truly,

E. W. Rice, Jr.

—— INDEX ——

OF

CURRENT ELECTRICAL LITERATURE.

&c. (November, 1887.)

TELEGRAPHY.

Telegraphing To and From Moving Trains. *N. Y. Elecn.*, Nov.

Train Telegraphy. *Rail. and Eng. Jour.*, Nov.

A Year's Work of the Signal Service. (Abst.) Gen. Greely's Report. *Rail. and Eng. Jour.*, Nov.

Annual Report, Western Union Telegraph Company 1886—7. *N. Y. Elecn.*, Nov.

On Induction between Wires and Wires. (Ill.) W. H. Preece, Brit. Asso. Ad. Sci.; *N. Y. Elecn.*, Nov.

Repeaters and Condensers. W. Maver, Jr. *Elec. World.*, Nov. 5.

Telegraph Repeaters. (Ill.) C. C. Capwell. *Elec. World.*, Nov. 5.

High Speed Telegraph Relay. (Ill. Corr.) S. D. Field. *Elec. World*, Nov. 5.

High Speed Telegraph Relays. (Corr.) S. J. M. Bear. *Elec. World*, Nov. 19.

The Writing Telegraph. (Ill.) *Elec. World*, Nov. 5.

Liability of the Telegraph Company. (Mistake made.) *Sci. Am.* Nov. 12.

A. B. & O. Reminiscence. (With portrait of R. Garrett.) *West. Elecn.*, Nov. 12.

On the Analogy between the Composition of Derivations in a Telegraph Circuit into a Resultant Fault, etc. A. E. Kennelly. (Ill.) *N. Y. Elec. Rev.*, Nov. 5.

The Dynamograph. *N. Y. Elec. Rev.*, Nov. 5.

The Phonic Wheel. P. La Cour. *Lond. Elec. Rev.*, Nov. 25.

The Phonic Wheel. (Corr.) Lord Rayleigh. *Lond. Elec. Rev.*, Nov. 4.

A Telegraph Company's Liability for Neglect. *N. Y. Elec. Rev.*, Nov. 12.

New Telegraph Key and Mechanical Telephone. (Lyman.) (Ill.) *West. Elecn.*, Nov. 19.

Long Distance Telegraphy. (Ed.) *Mod. Li. and Ht.*, Nov. 24.

Telegraph without Wires. (Ill.) *Sci. Am. Supp.*, Nov. 26.

Deep Sea Sounding and Submarine Telegraphy. E. Stallibrass, Soc. Tel. Engrs. and Elecns. *Lond. Elecn.*, Nov. 18; *Lond. Elec. Rev.*, Nov. 18; *Indust.*, Nov. 18.

Submarine Research. (Corr.) "X.X.X." *Lond. Elec. Rev.*, Nov. 18.

Deep-Sea Cable Soundings. (Corr.) C. Bright, Jr. *Lond. Elecn.*, Nov. 25.

Submarine Research. (Corr.) E. Stallibrass. *Lond. Elec. Rev.*, Nov. 25.

Cuttriss' Improved Siphon Recorder for Ocean Cables. (Ill.) *Lond. Elec. Rev.*, Nov. 25.

Cuttriss' Improved Siphon Recorder for Submarine Cables. (Ill.) *Elec. World*; *Lond. Elecn.*, Nov. 11.

Note on the Siphon Recorder and Ocean Telephony. T. D. Lockwood, Am. Inst. Elec. Engrs. *Elec. World*, Nov. 26; *West. Elecn.*, Nov. 26.

Recent Improvements in Apparatus for Ocean Telegraphy. (Ill.) C. Cuttriss, Am. Inst. Elec. Engrs. *Elec. World*, Nov. 26; *West. Elecn.*, Nov. 26.

A Big Feat in Cabling. ("Locrine" for the N. Y. Times.) *Elec. World*, Nov. 26.

Government and the Cables. *Lond. Elec. Rev*, Nov. 18.

Telegraphic Communication between England and France. *Telegraphist*, Nov.; *N. Y. Elec. Rev.*, Nov. 26.

The Government and the Channel Cables. (Ed.) *Lond. Elecn.*, Nov. 18.

Springs on Telegraph Wires. (Corr.) F. Higgins; F. Caws. *Lond. Elecn.*, Nov. 4.

Bardonnaut's "Sourdines." (Spring Mufflers.) (Ill.) *Lond. Elecn.*, Nov. 4.

Springs on Telegraph Wires. (Corr.) F. Caws. *Lond. Elecn.*, Nov. 25.

Some of the Results of Telegraphic Competition. (Ed.) *N. Y. Elecn*, Nov.

Government Telegraphs in England. *Elec. World*, Nov. 12.

Telegraph Rates. *Bradstreet's*; *N. Y. Elec. Rev.*, Nov. 19.

The Postal Telegraph—How the System works in England. *N. Y. Evg. Post*; *N. Y. Elec. Rev.*, Nov. 26.

TELEPHONY.

The Acoustic Principles Underlying Telephony. C. R. Cross, Boston Elec. Club ; *Md. Lt. and Ht.*, Nov. 24.

Theory of Telephone Circuits. (Ill.) V. Wietlisbach. *Elek. Rundschau; West. Elecn.*, Nov. 12, 26.

Telephone Investigations. (Ill.) J. R. Paddock. *Lond. Elec. Rev.*, Nov. 11.

Telephones. (Corr.) W. C. Barney. *Lond. Elec. Rev.*, Nov. 11.

A Method of Telephonic Communication between Ships at Sea. L. J. Blake, Am. Asso. Ad. Sci.; *Lond. Elecn.*, Nov. 4.

The Rise and Progress of Telephony in the United Kingdom. *Lond. Elecn.*, Nov. 4, 25, continued.

Swinton's Telephones. (Ill.) *Lond. Elec. Rev.*, Nov. 4.

Another Strong-Lunged Telephone. (Corr.) I. H. Farnham. *N. Y. Elec. Rev.*, Nov. 19.

Mix and Genest Microphone Telephone. (Ill.) *Sci. Am. Supp.*, Nov. 19.

Practical Telephony. I. T. D. Lockwood. *West. Elecn.*, Nov. 19.

Long Distance Telephony. *West. Elecn.*, Nov. 19.

Calling Generators for Telephone Exchanges. (Ill.) T. D. Lockwood. *Elec. World*, Nov. 19.

The Carbon Transmitter. (Corr.) W. C. Barney. *Lond. Elec. Rev.*, Nov. 18

That Telephone Concession in China. (F. Rae interview.) *West. Elecn.*, Nov. 5.

Progress in Telephony. *Iron and Steel Trades Jour; Sci. Am.*, Nov. 5.

Telephone Exchange Statistics. *N. Y. Elecn.*, Nov.

The Reis Telephone. (Corr.) C. J. Kintner. *N. Y. Elecn.*, Nov.

Notes on Long Distance Telephone Work. E. J. Hall, Jr., Nat. Tel. Ex. Assn.; *N. Y. Elecn.*, Nov.

Berliner's Gramophone. (Ill.) *Elec. World*, Nov. 12.

Leon Scott's Phonautograph of 1857. (Ill.) *Elec. World*, Nov. 12.

The New Edison Phonograph. *N. Y. World; Elec. World*, Nov. 12; *Sci. Am.*, Nov. 19.

Repeating Electric Phonograph. (Ill.) R. M. Hunter. *Elec. World*, Nov. 26.

Edison's Perfected Phonograph. *Evg. Post; N. Y. Elec. Rev.*, Nov. 5.

Edison's New Phonograph. *West. Elecn.*, Nov. 19.

ELECTRIC LIGHT, ETC.

Electric Lighting of the Paris Hippodrome. *Lond. Elec. Rev.*, Nov. 18.

The "Blakey-Emmott" Dynamo. (Ill.) *Lond. Elecn.*, Nov. 18; *Lond. Elec. Rev.*, Nov. 18; *Indust.*, Nov. 18.

The Electric Light in Leamington. *Lond. Elec. Rev.*, Nov. 18.

The Lighting of Leamington. *Lond. Elecn.*, Nov. 18.

Electric Lighting on Steam Yacht "Thetis." *Lond. Elecn.*, Nov. 18; *Lond. Elec. Rev.*, Nov. 18; *Indust.*, Nov. 18.

Electric Light Switchboard. (Clark-Muirhead.) (Ill.) *Lond. Elecn.* Nov. 18.

Irradiation. (Ill.) G. M. Hopkins. *Sci. Am.*, Nov. 26.

The Electric Light in New York. *City Record; N. Y. Elec. Rev.*, Nov. 26.

Intrinsic Brilliancy of Some Lights. (Note.) Monnier. *N. Y. Elec. Rev.*, Nov. 26.

The Luther Arc Lamp. (Hanson.) (Ill.) *Lond. Elec. Rev.*, Nov. 11.

Note on the Insulation of Electric Light Conductors. (R. V. Picore. *L'Electricien; Lond. Elecn.*, Nov. 11.

The Electric Light and Tramway at Blackpool. (Ed.) *Lond. Elecn.*, Nov. 11. (Banquet to Electricians at Blackpool).

Electric Light for Mines. *Lond. Elec. Rev.; Science; N. Y. Elec. Rev.*, Nov. 12.

Luminous Organs of an Insect. *Md. Lt. and Ht.*, Nov 17.

Regulations of the Boston Fire Underwriters Union. *N. Y. Elec. Rev.*, Nov. 12.

Artificial Light. R. J. Monks. *N. Y. Elec. Rev.*, Nov. 12.

New Woodhouse and Rawson Switch. (Ill.) *Lond. Elecn.*, Nov. 4.

The Working of Arc Lamps. (Corr.) J. G. Statter. *Lond. Elec. Rev.*, Nov. 4.

Bruce's Balloon Signals in Belgium. *Lond. Elecn.*, Nov. 4.

The Clark Arc Lamp. (Ill.) *N. Y. Elec. Rev.*, Nov. 5.

Hedge's Switches and Mica Foils. *Lond. Elec. Rev.; N. Y. Elec. Rev.*, Nov. 5.

The Electric Light not a "Fire Bug." (Fire Statistics.) *St. Louis Globe Dem.; Elec. World*, Nov. 19.

List of Edison Central Stations, June, 1887. *N. Y. Elecn.*, Nov.

Electric Lighting and Gas. (Oudin Factory.) *Lond. Elec. Rev.*, Nov. 18.

The New Installation at Lloyds, Barnetts and Bosanquet's Bank. (Switchboard.) (Ill.) *Lond. Elec. Rev.*, Nov. 18.

Photographing Bullets in Motion by the Electric Light. (Note.) (H. Mach.) *Lond. Elec. Rev.*, Nov. 25.

The Effects of Electric Light Induction on the Telephone. B. E. Sunny, Chic. Elec. Club; *Elec. World*, Nov. 12; *West. Elecn.*, Nov. 12.

Estimating the Cost of the City Plant, Chicago. *West. Elecn.*, Nov. 5

The Electric Light and Telephone Under Water. (Ill.) *Cassell Fam. Mag.; West. Elecn.*, Nov. 5.

The Electric Light for a Fire Department. (Barrett portable apparatus.) *West. Elecn.*, Nov. 5.

Radiation from Dull and Bright Surfaces. J. T. Bottomley *Elec. World*, Nov. 5.

The Cost of Domestic Electric Lighting. D. Salomons. *Indust.*; *West. Elecn.*, Nov. 5., (concl'd); *Elec. World*, Nov. 19.

Sir F. Abel on Electric Safety Lamps. Inst. Civ. Eng'rs; *Lond. Elecn.*, Nov. 18.

The Elements of Electric Lighting. (Ill.) P. Atkinson. *West. Elecn.*, XVI., Nov. 5; XVII., Nov. 12; XVIII., Nov. 19; XIX., Nov. 26.

Pitkin's Portable Lamp. (Ill.) *Lond. Elecn.*, Nov. 4; *N. Y. Elec. Rev.*, Nov. 26.

The Electric Light in Mines. (Ed.) *Science*, Nov. 4.

Manufacture of Carbons. (Liepmann Process.) *Lond. Elec. Rev.*, Nov. 18

The Manufacture of Carbon Electrodes. (Liepmann.) *Eng.* Nov. 18.

The Manufacture of Electric Light Carbons. (Liepmann.) *Indust.*, Nov. 18.

The Liepmann Carbon Works. *Lond. Elecn.* Nov. 18.

Car Lighting in France—The Pintsch System. (Corr.) G. L. Fowler. *R'd. Gas.*, Nov. 11.

Lighting Trains by Electricity. (Automatic.) (Ill.) T. P. Carswell. Phil. Soc. Glasgow; *N. Y. Elecn.*, Nov.

The Electric Light and Railways in Great Britain. *Lond. Elec. Rev.; N. Y. Elec. Rev.*, Nov. 26.

The Electric Light and Railways. (Ed.) *Lond. Elec. Rev.*, Nov. 4.

Lighting Railroad Trains. Abstract of report to Int. Railroad Cong., Milan; *R'd Gas.*, Nov. 18.

An Incandescent Gas Light. *Iron; Sci. Am.*, Nov. 5.

The Advantages of Gas Companies Engaging in the Electric Light Business. E. J. King, Am. Gas Light Asso., Oct.; *N. Y. Elec. Rev.*, Nov. 12.

Cheap Gas. (Ed.) *N. Y. Elec. Rev.*, Nov. 26.

The Thomson-Houston System of Electric Lighting. *Lond. Elec. Rev.*, Nov. 25.

The Progress of the Thomson-Houston System. *Lond. Elecn.*, Nov 25.

The American System of Arc Lighting. *Lond. Elec. Rev.*, Nov. 18.

DYNAMOS, SYSTEMS OF DISTRIBUTION, ETC.

Electrical Distribution by Alternating Currents. M. M. M. Slattery, Nat. Elec. Lt. Asso.; *Lond. Elec. Rev.*, Nov. 25.

Distribution by Transformers. (Corr.) R. Mitchell, *N. Y. Elecn.*, Nov.

Early Work in Induction Systems. Historical List. (Corr.) R. Mitchell. *Elec. World*, Nov. 5,

Paris & Scott's Continuous-Current Transformer at the Newcastle Exhibition. *Lond. Elecn.; N. Y. Elec. Rev.*, Nov. 19.

Jehl and Rupp's Rotating Transformers. (Ill.) *Lond. Elecn.; N. Y. Elec. Rev.*, Nov. 19.

The Westinghouse System of Electric Lighting. G. L. Addenbrooke. *Lond. Elec. Rev.*, Nov. 4.

Jehl and Rupp's System of Continuous Current Transformers. *Lond. Elecn.*, Nov. 11.

Paris & Scott's Continuous Current Transformer. *Lond. Elecn.; West. Elecn.*, Nov. 19.

Notes on Alternating Currents. (Ill.) J. A. Fleming. *Lond. Elecn.*, Nov. 18.

On the Geometrical Method of Determining the Conditions of Maximum Efficiency in Transmission of Power by Alternating Currents. T. H. Blakesley, Eng. Phys Soc.; *Lond. Elecn.*, Nov. 18; *Lond. Elec. Rev.*, Nov. 18.

The Lever Dynamo. Intersection of polar armatures in the pole pieces.. (Corr.) H. Jones. *Lond. Elec. Rev.*, Nov. 25.

The Lever Dynamo. (Corr.) C. Lever. *Lond. Elec. Rev.*, Nov. 4.

The Iron-Clad Dynamo. (Corr.) W. F. Collins. *Elec. World*, Nov. 26.

The Lever Dynamo. (Ill.) *Elec. World*, Nov. 12.

Constant Current Dynamo. (Trotter.) (Ill.) *Indust.; West. Elecn.*, Nov. 12.

Rowland's Dynamo of 1869. (Corr.) L. Duncan. *N. Y. Elec. Rev.*, Nov. 5.

Statter Dynamo. (Ill.) *Lond. Elec. Rev.*, Nov. 4.

Paterson & Cooper's New Dynamos. (Ill.) *Lond. Elec. Rev.*, Nov. 4.

Constant Current Dynamo. (Statter.) (Ill.) *Indust.; N. Y. Elec. Rev.*, Nov. 12.

Lighting from Central Stations. (Ed.) *Lond. Elec. Rev.*, Nov. 18.

An Automatic Current Regulator for Constant Current or Constant Potential. (Ill.) Jehl and Rupp. *Lond. Elecn.*, Nov. 25.

Dynamo Machines with Automatic Regulation for Constant Current. (Corr.) E. Desroziers. *Indust.*, Nov. 25.

Coupling of Dynamos on the same External Circuit. (Ill.) C. C. Haskins, Chic. Elec. Club. *West. Elecn.*, Nov. 26.

Long Runs of Engines and Dynamos. *Lond. Elecn.*, Nov. 4.

The Patten System of Dynamo Construction. (Ill.) *Elec. World*, Nov. 26.

Field Magnets for Dynamo Machines and their Comparative Merits. (Ill.) (W. E. Fein.) *Cent. fur Elek.; N. Y. Elec. Rev.*, Nov. 5.

An Analysis of Dynamo Design. F. C. Wagner, Am. Asso. Ad. Sci.; *Lond. Elec. Rev.*, Nov. 4.

ELECTRIC POWER, ETC.

The Electric Motor and the Derrick. (Ill.) *West. Elecn.*, Nov. 26.

Pumping by Electricity in Coal Mines. (Normanton plant.) *Lond. Elec. Rev.*, Nov. 18.

Mine Pumps Driven by Electricity. (Normanton.) *Eng.*, Nov. 18.

Pumping by Electricity in Coal Mines. (Forest of Dean.) (Corr.) F Brain. *Lond. Elec. Rev.*, Nov. 25.; *Lond. Elecn.*, Nov. 25.

An Electric Mine Pump. (Normanton Plant.) *Indust.*, Nov. 18.

Electrical Pumping Plant at St. John's Colliery, Normanton, (Immisch motor.) *Lond. Elecn.*, Nov. 18.

Elevator Driving with Sprague Motor. (Ill.) *Elec. World*, Nov. 12.

Electric Motors in England. *N. Y. Elec. Rev.*, Nov. 12.

The Card Electric Motor. (Ill.) *Elec. World*, Nov. 5; *West. Elecn.*, Nov. 5.

The Card Retouching Machine for Photographers. (Ill.) *West. Elecn.* Nov. 12.

The Card Electric Motor. (Ill.) *Lond. Elecn.*, Nov. 25.

An Electric Launch. *Indust.; West. Elecn.*, Nov. 12.

Thone Electric Motor. (Ill.) *N. Y. Elec. Rev.*, Nov. 12.

The Thone Electric Motor. (Ill.) *Elec. World*, Nov. 12.

The Hyer Electric Motor at the Electrical Exhibition. (Ill.) *Elec. World*, Nov. 12.

Prof. Houston and the Hyer Motor. (Corr.) E. J. Houston. *Elec. World*, Nov. 26.

The Hyer Motor. (Corr.) W. E. Hyer. *Elec. World*, Nov. 26.

Anticipation of the Hyer Motor. (Corr.) R. Eickemeyer. *Elec. World*, Nov. 19.

Test of Immisch Thirty Horse-Power Motor. *Elec World*, Nov. 26.

Electric Motors for the Spanish Navy. (Immisch.) *Lond. Elecn.*, Nov. 4.

Immisch's Electro-Motors. *Lond. Elec. Rev.*, Nov. 4.

The Field Electric Locomotive. (Ill.) *Elec. World; R'd. Gaz.*, Nov. 11.

Electricity on Street Railways. (Ed.) *N. Y. Elecn.*, Nov.

Electricity as a Motive Power. W. Wharton, Jr.; Am. St. Ry. Asso., Oct.; *N. Y. Elecn.*, Nov.

The American Street Railway Association Annual Meeting. *N. Y. Elecn.*, Nov.

The Largest Electric Street Car in the World. (Reckenzaun, Phila.) *Elec. World*, Nov. 5.

The Weiss System of Street Car Motors. (Storage.) (Ill.) *Sci. Am.*, Nov. 12.

The Philadelphia Street Railway Convention. (Wharton's paper.) *Lond. Elec. Rev.*, Nov. 18.

Electric Tram Cars. (Huber and Herbrand.) *Indust.*, Nov. 25.

Electric Street Tram Cars. (Corr.) R. Ward. *Eng.*, Nov. 25.

Electric Street Tram Cars. (Ed.) *Eng.*, Nov. 18.

The Electric Railways in America. C. J. Van Depoele, Am. St. Ry. Asso. *Lond. Elec. Rev.*, Nov. 25.

The Application of Electricity to Street Railways. F. J. Sprague, Am. St. Ry. Asso. *Lond. Elec. Rev.*, Nov. 25.

The Argument against Storage Batteries for Electric Traction. R. W. Blackwell, Am. St. Ry. Asso. *Lond. Elecn.*, Nov. 25.

The Field Electric Locomotive. (Ill.) *Indust.*, Nov. 18.

The Daft Electric Railway at Asbury Park, N. J. (Ill.) *Elec. World*, Nov. 19.

The New Reckenzaun Car in Philadelphia. *Elec. World*, Nov. 19.

The Lykens Valley Mine Electric Railway. *Elec. World*, Nov. 19.

The Brussels Electric Tramway. *N. Y. Elec. Rev.*, Nov. 5.

Electric Street Cars. (Corr.) G. Percival. *Lond. Elec. Rev.*, Nov. 4.

On Electric Street Cars, with Special Reference to Methods of Gearing. A. Reckenzaun, Am. Inst. Elec. Eng'rs, Sept. *Lond. Elecn.* Nov. 4, concl'd.

The Bentley-Knight System of Electric Tramway. *Md. Lt. and Ht.*, Nov. 17.

Electric Street Railways Indorsed. Opinions of Mayors of Scranton, Pa., Montgomery, Ala., and Lima, O. *West. Elecn.*, Nov. 19.

Spur-Gearing for Electric Tram Cars. (F. J. Sprague.) *Elec. World*, *Lond. Elecn.*, Nov. 11.

Distance Traveled by Storage Battery Cars. (Corr.) C. O. Mailloux. *Elec. World*, Nov. 26.

Electric Traction on the West Metropolitan Tramway. *Lond. Elecn.*, Nov. 18.

Distribution of Power. *Wood and Iron; Sci. Am.*, Nov. 5.

Mechanical Traction on Street Railways. (Ed.) *Indust.*, Nov. 18.

Electricity, Steam, Cable or Horse Power. *West. Elecn.*, Nov. 12.

The Motive Power of the Future. *Am. Jour. Ry. Appl.; Mechanics*, Nov.

The Electric Current as a Means of Increasing the Tractive Adhesion of Railway Motors and other Rolling Contacts. E. E. Ries, Am. Asso. Ad. Sci. *Lond. Elec. Rev.*, Nov. 4.

The Ries Electric Traction-Increasing Apparatus for Railways. *Elec. World; Lond. Elecn.*, Nov. 4.

Electric Motors vs. Steam Engines. C. M. Barclay. *West. Elecn; Lond. Elec. Rev.*, Nov. 4.

Electric Transmission of Energy. *Eng. and Mining Jour.; N. Y. Elec. Rev.*, Nov. 12.

INSTRUMENTS, MEASUREMENTS, &c.

A Coulomb Meter or Instrument for Measuring the Consumption of Electricity. (Ill.) G. Forbes, Am. Inst. Elec. Eng'rs, Oct.; *N. Y. Elecn.*, Nov.

Another New Coulomb Meter. (Borel & Paccaud.) *N. Y. Elec. Rev.*, Nov. 19.

A Current Meter. (Ill.) Jehl & Rupp. *Sci. Am. Supp.*, Nov. 19.

Discussion on Prof. Forbes' Meter at the American Institute of Electrical Engineers. *Lond. Elecn.*, Nov. 4.

A Formula Giving the Size of Wire for Incandescent Lighting. C. S. Bowie. *Elec. World*, Nov. 5.

A Method of Making a Selenium Cell of Constant Resistance. (Mercadier.) *Lond. Elecn.*, Nov. 11.

A Foucault-Current Water-Heater. (Note.) *Lond. Elecn.*, Nov. 25.

A Water Level Indicator. (Tucker.) *Lond. Elecn.*, Nov. 11.

A Novel Thermostat. (Morrison.) (Ill.) *Elec. World*, Nov. 19.

Tachometers and Tachographs. (Ill.) F. B. Badt. *West. Elecn.*, Nov. 5.

New Combination Sets. (Apparatus of Globe Electric Co.) (Ill.) *West. Elecn.*, Nov. 19, 26.

An Electric Fire-Damp Indicator. (Swan.) Brit. Asso. Ad. Sci., Sept.; *Elec. World*, Nov. 19.

Hughes's Induction Balance. J. Cook. *Nat.; Lond. Elec. Rev.*, Nov. 4.

An Electric Level Regulator. *N. Y. Elec. Rev.*, Nov. 19.

A Null Method in Electro-Calorimetry. (Ill.) Stroud & Haldane, Brit. Asso. Ad. Sci ; *Elec. World*, Nov. 5.

Haynes' Kinemeter. (Ill.) *R'd. Gas.*, Nov. 18.

A New Compass. (Sirieix.) *Alta. Cal.; Sci. Am.*, Nov. 12.

The Research Laboratory of Mr. Edward Weston. (Ill.) *Sci. Am.*, Nov. 5.

Standard Lamps. A. V. Harcourt, Brit. Asso. Ad. Sci. *Elec. World*, Nov. 12.

The Telemeter System. (Ill.) R. F. Upton, Brit. Asso. Ad. Sci. *Sci Am. Supp.*, Nov. 19.

The Waterhouse Standard Ammeter. (Ill.) *Sci. Am. Supp.*, Nov. 5.

The Wood Ammeter and Voltmeter. (Ill.) *Elec. World*, Nov. 26.

A Priority Claim on Repulsion Ammeters. (Corr.) J. J. Wood. *Elec. World*, Nov. 26.

A New Electric Meter. (Dyer.) (Ill.) *Elec. World*, Nov. 5.

A New Voltmeter. (Siemens-Halske.) *Elec. World*, Nov. 19.

Meters and Meters. (Ed.) *Md. Lt. and Ht.*, Nov. 24.

New Electric Balances. (Ill.) W. Thomson, Brit. Asso. Ad. Sci. *N. Y. Elecn.*, Nov.

Communication from Prof. Sordet on the Non-Magnetic Balance. (Corr.) E. Sordet. *N. Y. Elec Rev.*, Nov. 5.

A Chart of Wire Gauges. (Ill.) S. S. Wheeler. *Elec. World*, Nov. 12.

Comparison of the New British Legal Standard Wire Gauge with the Old British Gauge (B. W. G.) and the American Gauge. *Mechanics*, Nov.

MISCELLANEOUS.

Electric Slot Semaphore Signal. (Ill.) *Ry. Eng'r.; R'd. Gas.*, Nov. 11.

The Electric Current. F. C. Van Dyck. *N. Y. Elecn.*, Nov.

Dynamic Electricity. IX. Carl Hering. *N. Y. Elecn.*, Nov.

Uses of Electricity in Mills. C. J. H. Woodbury. *N. Y. Elecn.*, Nov.

A Permanent Technical Exhibition at St. Petersburg. *N. Y. Elecn.*, Nov.

Obituary. G. R. Kirchoff and O. E. Woodhouse. *N. Y. Elecn.*, Nov.

The End of Electrical Invention not Yet. E. J. Houston. *Elec. World*, Nov. 5.

Patten's Electric Annunciator Service. (Ill.) *Elec. World*, Nov. 5.

The New "Bartholdi" Automatic Burner. (Electric Gas Lighter.) (Ill.) *Elec. World*, Nov. 5.

A Repeating Bell. (Cox.) (Ill.) *West. Elecn.*, Nov. 5.

Diagram for Electric Wiring. (Note on Stark's Diagram.) *West. Elecn.*, Nov. 5.

He Thought a Hole through a Board. (Visit to Weston Laboratory.) *N. Y. Herald; West. Elecn.*, Nov. 5.

The Bell Cord Done Away With. (Cregier.) *West. Elecn.*, Nov. 12.

How Electricity is made. (Ill.) B. A. Fiske. *Rd. and Eng. Jour.*, Nov.

A Sham Torpedo Battle. *N. Y. Herald; Rd. and Eng. Jour.*, Nov.

Electricity Applied to Railway Brakes. (Minneapolis tests.) *La Lum. Elec.; Lond. Elec. Rev.*, Nov. 18.

Notes from Scandinavia. *Lond. Elec Rev.*, Nov. 18.

Scientific Toys—The Magic Oracle. (Ill.) *La Nat.; Lond. Elec. Rev.*, Nov. 25.

Accidents in Mines. (Abst.) F. A. Abel, Inst. Civ. Eng'rs; *Indust.*, Nov. 25.

Sketch of the Principal Electrical Papers read before Section A During the Late Meeting of the British Association at Manchester, 1887. O. J. Lodge. *Lond. Elec. Rev.; N. Y. Elecn.*, Nov.

Specific Inductive Capacity. J. Hopkinson, Royal Soc. *Lond. Elec Rev.*, Nov. 25.

The Electric Current. F. C. Van Dyck. *N. Y. Elecn.; Lond. Elec. Rev.*, Nov. 25.

Letters for Learners. I. (Ill.) A. E. Kennelly. *Lond. Elecn.*, Nov. 18.

Letters for Learners and Non-Professional Readers. (Ill.) A. E. Kennelly. *Lond. Elecn.*, No. 25. Chap. II.—Batteries.

Mercurial Air Pumps. S. P. Thompson, Soc. Arts. *Lond. Elecn.*, Nov. 25; *Eng.*, Nov. 25.

Action of Oil on Metals. (Corr.) "W." *Lond. Elec. Rev.*, Nov. 18.

The Electrical Condition of the Peak of Teneriffe. *Nat.; Lond. Elec. Rev.*, Nov. 25.

A French Automatic Fire Alarm. E. Genglaire. *L'Electricité; West. Elecn.*, Nov. 12.

A Convenient Pocket Tool for Electrical Workers. (Hammer's.) (Ill.) *N. Y. Elec. Rev.*, Nov. 5.

The Government and Applied Science. (Ed.) *N. Y. Elec. Rev.*, Nov. 19.

Modern Views of Electricity. (Ill.) O. J. Lodge. Parts II, III. *Nat.; Lond. Elec. Rev.*, Nov. 4.

Modern Views of Electricity. IV. (Ill.) O. J. Lodge. *Nat. Lond. Elec. Rev.*, Nov. 11.

On the Physical Properties of a Nearly Non-Magnetizable (Manganese) Steel. W. F. Barrett, Brit. Asso. Ad. Sci. *Lond. Elecn.*, Nov. 4.

The New View of Magnetism. (Ill.) S. S. Wheeler. *N. Y. Elec Rev.*, Nov. 12.

The Earth's Internal Heat. *Md. Lt. and Ht.*, Nov. 17.

Thomas' Electrical Alarm Clock. (Ill.) *West. Elecn.*, Nov. 19.

The Use of Electricity for Treating Gold and Silver Ores. (Molloy.) *Lond. Elecn.*, Nov. 11.

A Novel Electric Lock. (Fuller, Holtzer.) (Ill.) *Elec. World*, Nov. 26.

Improved Watchman's Clock. (New Haven Clock Co.) (Ill.) *N. Y. Elec. Rev.*, Nov. 26.

Iron or Wooden Poles. *N. Y. Herald*, Nov. 13; *N. Y. Elec. Rev.*, Nov. 26.

Earth Currents in Large Conductors. (Stefan.) *N. Y. Elec. Rev.*, Nov. 26.

Experiments on the Rate of Propagation of an Electric Current. (Hagerbach.) *Wied. Ann.* Vol. XXIX, p. 377; *Lond. Elecn.*, Nov. 4.

Rate of Propagation of Current. (Hagerbach's tests.) *Wied. Ann.; N. Y. Elec. Rev.*, Nov. 26.

An Improved Earth Plate. (Dorn.) *Elek. Zeit, Lond. Elecn.*, Nov. 4; *Sci. Am.*, Nov. 26.

The American Institute Exhibition. (Ed.) *Sci. Am.*, Nov. 12.

Notes on the American Institute Electrical Exhibition. (Daft, Washburn & Moen, Silliman.) *Elec. World*, Nov. 5.

Notes on the American Institute Electrical Exhibition. (Thomson Welding; Metropolitan Ventilating System.) *Elect. World*, Nov. 12.

American Institute Electrical Exhibition. (Grossman, Tropical Am. Telephone Co.) *Elec. World*, Nov. 19.

The American Institute Fair. *N. Y. Elec. Rev.*, Nov. 19.

Revision of the Patent Law Proposed by the National Electric Light Association. *N. Y. Elecn.*, Nov.

Improvements in the Patent System. R. M. Hunter. *Elec. World*, Nov. 12.

The National Electric Light Association and Patent Legislation. *Elec. World*, Nov. 5.

For Patent Office Reforms. *West. Elecn.*, Nov. 12.

The Movement for Patent Reform. *Elec. World*, Nov. 19.

A Plain Statement of the Case. (Patent Reform.) (Ed.) *Md. Lt. and Ht.*, Nov. 17.

Magnetism in Time Pieces. (E. Sordet.) *West. Elecn.*, Nov. 19.

The Geneva Non-Magnetic Watch. *Sci. Am.; N. Y. Elec. Rev.*, Nov. 26.

Magnetism in Watches. C. C. Haskins, Bro. Loco-Eng'rs, Oct.; *West. Elecn.*, Nov. 5; *N. Y. Elec. Rev.*, No 5.

Lightning. (Ed.) *Eng.*, Nov. 11.

Atmospheric Electricity. L. Weber. *Sci. Am.*, Nov. 12.

Danger from Lightning. A. E. Dolbear. *Sci. Am.*, Nov. 12.

Lightning Statistics in Germany. *La Lum. Elec.*; *Lond. Elec. Rev.*, Nov. 4.

Prof. Tyndall on Lightning Conductors. *Lond. Times*; *Sci. Am.*, Nov. 26.

Underground and Aerial Cables. B. E. Sunny, Nat. Tel. Ex. Asso.; *N. Y. Elecn.*, Nov.

Underground Wires. (Corr.) T. O. Callender. *Lond. Elec, Rev.*, Nov. 4.

The Pyromagnetic Generator. (Corr.) W. B. Cooper. *N. Y. Elec. Rev.*; *Jour. Fkln. Inst.*, Nov.

The Cowles Electric Furnace and the Aluminum Alloys. *Lond. Elecn.*, Nov. 4.

Aluminum Bronze for Great Guns. (Cowles process.) A. H. Cowles, Naval Inst. *Sci. Am.*, Nov. 26.

Electric Welding. (Ill.) *Sci. Am.*, Nov. 26.

A New Electric Welding Apparatus. (Bernardo and Olszewsky process.) *Indust.*, Nov. 18.

Bernado's Method of Electric Welding. (Ill.) *Elek. Zeit.*, Nov.; *Lond. Elecn.*, Nov. 25.

The Teaching of Electricity. (Corr.) W. Larden. *Lond. Elecn.*, Nov. 18.

South Kensington Examination Papers. *Lond. Elecn.*, Nov. 11.

The Electrical Engineering Department at Cornell. *N. Y. Elecn.*, Nov.; *West. Elecn.*, Nov. 5.

The Training of Electrical Engineers. (Ed.) *Lond. Elecn.*, Nov. 25.

Higher Education in Japan. Sawai. *West. Elecn.*, Nov. 19.

Prof. S. P. Thompson on Technical Education. *Lond. Elecn.*, Nov. 11.

What are the Requirements for a Course in Electrical Engeneering at a Technical School. F. R. Hutton. *School of Mines Quarterly*; *N. Y. Elec. Rev.*, Nov. 26.

BATTERIES, ELECTROLYSIS, &c.

Reckenzaun's Secondary Battery. (Ill.) *Sci. Am. Supp.*, Nov. 5.

"Excess" Alarms for Secondary Batteries. (Ill.) *Lond. Elecn.*, Nov. 25.

Hering's Secondary Battery. *Elec. World*, Nov. 19.

The Desmazures Storage Battery. *Elec. World*, Nov. 19; *Sci. Am.*, Nov. 19.

A New Secondary Battery. (Tamine.) *Lond. Elecn.*, Nov. 4; *N. Y. Elec. Rev.*, Nov. 19.

Storage Batteries for Electric Locomotion. A. Reckenzaun. *Sci. Am. Supp.*, Nov. 19.

Elieson's New Secondary Battery. (Ill.) *Lond. Elec. Rev.*, Nov. 4; *N. Y. Elec. Rev.*; Nov. 26.

New Ingredient for the Storage Battery. *N. Y. Elec. Rev.*, Nov. 12.

The Desmasures Secondary Battery. E. Reynier. *Monit. Indust.*, Nov. 3.; *Lond. Elecn.*, Nov. 11.

New Secondary Battery. (Desmazures.) *N. Y. Elec. Rev.*, Nov. 26.

The Wildt Leclanché Battery. (Ill.) *Elec. World*, Nov. 19.

Improvements in Batteries. (Montanus and Hasslacher.) *Revue Scientifique*; *N. Y. Elec. Rev.*, Nov. 26.

The Stanley Faradic Battery. (Ill.) *Elec. World*, Nov. 12.

The Bennett Primary Battery. (Corr.) A. R. Bennett. *Lond. Elecn.*, Nov. 18; *Lond. Elec. Rev.*, Nov. 18.

The Schanschieff Battery and Lamps. *Lond. Elec. Rev.*, Nov. 25.

Schanschieff's Solution for Primary Batteries. *N. Y. Elec. Rev.*, Nov. 26.

New Composition for Leclanché Batteries. (Bender and Francken.) *N. Y. Elec. Rev.*, Nov. 26.

Primary Batteries. (Corr.) W. Webster, Jr. *Lond. Elec. Rev.*, Nov. 25; *Lond. Elecn.*, Nov. 25.

Primary Batteries for Illuminating Purposes. P. F. Nursey, Soc. of Eng'rs. *Lond Elecn.*, Nov. 11; *Lond. Elec. Rev.*, Nov. 11, (et seq.)

Primary Batteries for House Lighting. (Corr.) O. C. D. Ross. *Lond. Elecn.*, Nov. 11; *Lond. Elec. Rev.*, Nov. 11.

Primary Batteries. (Ed.) *Lond. Elec. Rev.*, Nov. 11.

Primary Batteries for House Lighting. (Corr.) N. G. Thompson. *Lond. Elecn.*, Nov. 18.

Electro-Plating Flowers. *West. Elecn.*, Nov. 5.

Electro-Plating Organisms. *Eng; Elec. World*, Nov. 19.

Electrolysis of Cobalt Salts. A. Watt. *Lond. Elec. Rev.*, Nov. 18, Nov. 25. (Cont'd.)

Electrolysis of Iron Salts. A. Watt. *Lond. Elecn.*, Nov. 11.

Electrolysis of Iron Salts. A. Watt. *Lond. Elecn.*, Nov. 25. (Cont'd.)

Experiments on the Possible Electrolytic Decomposition of Certain Alloys. (Ill.) W. C. Roberts-Austen. *Lond. Elecn.*, Nov. 25.

Electrolysis of Sulphites. *Lond. Elec. Rev.; N. Y Elec. Rev.*, Nov. 19.

Electrolysis and Refining of Sugar. (Ill.) *Sci. Am. Supp.*, Nov. 19.

Electrolytic Inlaid Work. *Cent. fur Opt. und Mech.; Sci. Am.*, Nov. 19.

On Electrolytic Convection Currents. (Abst.) F. Richarz. *Verhandl. d. physik. Gesellsch. z. Berlin. Lond. Elecn.*, Nov. 4. (Rept. to Electrolysis Com. Brit. Asso.)

A Voltaic Element with Movable Plates. *L'Electricité; West. Elecn.*, Nov. 5.

The Part Played by Electricity in Crystallization. (Ill.) Decharme's Investigations. *Sci. Am. Supp.*, Nov. 5, Nov. 12.

On the Theory of Electric Endosmose and Allied Phenomena, and on the Existence of a Coefficient in Contact with a Solid. Prof. Lamb, Brit. Asso. Ad. Sci. *Lond. Elecn.*, Nov. 4.

On the Mode of Formation of Hydrogen Peroxide During the Electrolysis of Dilute Sulphuric Acid. (Abst.) F. Richarz. *Wied. Ann. XXXI., p. 912. Lond. Elecn.*, Nov. 4. (Rept. to Electrolysis Com. Brit. Asso.)

MECHANICAL, &c.

A New Motor or Traction Power. (Clark.) (Ill.) *Md. Lt. and Ht.*, Nov 17.

Clark's Traction Wheel. (Ill.) *Md Lt. and Ht.*, Nov. 24.

The Russell Automatic Engine for Electric Lighting. (Ill.) *Elec. World*, Nov. 19.

Russell & Co's. Automatic Engines. (Ill.) *West. Elecn.*, Nov. 19.

Russell & Co's. Automatic Engines. (Ill.) *N. Y. Elec. Rev.* Nov. 19.

Wave Power Motor. (Steen.) *San. Fran. Call.; Sci. Am.*, Nov. 26.

Utilising Wave Power. *San. Fran. Call.; N. Y. Elec. Rev.*, Nov. 26.

Niagara Falls Water Power. *N. Y. Evg. Post; Sci. Am.*, Nov. 26.

The Baldwin Gas Engine for Electric Lighting at the Electrical Exhibition. (Ill.) *Elec. World*, Nov. 26.

Gas Engines Employed in a Central Station Plant. *N. Y. Elecn.*, Nov.

Guarantees with Steam Plants. R. Grimshaw. *Proc. Mech.; N. Y. Elec. Rev.*, Nov. 19

Friction Driving Gear for Dynamos. (Ill.) (Raworth). *Eng.*, Nov. 25.

Practical Analogies between Mechanical and Electrical Engineering. (Ill.) H. F. Watts. *Elec. World*, Nov. 5.

Combined Heater, Purifier and Pump. (Clarkson. (Ill.) *West. Elecn.* Nov. 12.

Reference List of Leading Authorities Cited.

NAME.	ABBREVIATION.	PUBLISHED, &c.
Engineering.	*Eng.*	London, 35–36 Bedford St. W. C.; weekly. £1.16.
Industries.	*Indust.*	Manchester, 70 Market St., weekly. £1.12.
The Electrician.	*Lond. Elecn.*	London, 1 Salisbury Court, E. C.; weekly. £1.2.
The Telegraphic Journal and Electrical Review.	*Lond. Elec. Rev.*	London, 22 Paternoster Row, E. C.; weekly. £1.1.8.
The Electrical Engineer	*Lond. Elec. Engr.*	London, 139–140 Salisbury Court; monthly. 3d. per issue.
The Telegraphist.	*Telegraphist.*	London, 74–76 Great Queen St., W. C.; monthly, 2d. per issue.
Nature.	*Nat.*	London, 29 Bedford St,, W. C.; weekly, £1.8.
Knowledge.	*Knowledge.*	London, 39 Paternoster Row; monthly, 6d. per issue.
India Rubber & Gutta Percha & Electrical Trades Journal.	*I. R. & G. P. Jour.*	London, 115 Finsbury Pavement, E. C.; monthly. 15 shillings.
The Electrical Engineer	*N. Y. Elec. Engr.*	New York, 115 Nassau St.; monthly, $
The Electrical World.	*Elec. World.*	New York, 168–177 Potter Building; weekly. $3.
The Electrical Review.	*N. Y. Elec. Rev.*	New York, 13 Park Row; weekly. $3.
The Electric Age.	*Elec. Age.*	New York, 74 Cortlandt St; semi-monthly, $1.50.
Modern Light and Heat.	*Md Lt and Ht.*	Boston, 178 Devonshire St.; weekly, $3
Western Electrician.	*West. Elecn.*	Chicago, 6 Lakeside Building; weekly, $2.
Journal of the Franklin Institute.	*Jour. Fkln. Inst.*	Philadelphia, Franklin Institute; monthly, $5.
Science.	*Science.*	New York, 47 Lafayette Place, weekly, $3.50.
Scientific American.	*Sci. Am.*	New York, 361 Broadway; weekly, $3.
Scientific American Supplement.	*Sci. Am. Supp.*	New York, 361 Broadway; weekly, $5.
Mechanics.	*Mech.*	Philadelphia, 907 Arch St.; monthly, $1.
Railroad Gazette.	*R'd. Gaz.*	New York, 73 Broadway; weekly, $4.20.
American Machinist.	*Am. Mach.*	New York, 96 Fulton St.; weekly, $2.50.
Street Railway Journal	*St. Ry. Jour.*	New York, 113 Liberty St.; monthly, $2.
Street Rajlway Gazette.	*St. Ry. Gaz.*	Chicago, 9 Lakeside Building; monthly, $2.
Light, Heat and Power.	*Lt. Ht. and Pr.*	Philadelphia, 413 Walnut Street; semi-monthly, $3.
Progressive Age.	*Prog. Age.*	Philadelphia, 333 Walnut St.; monthly, $2.
Railroad and Engineering Journal.	*Rd. and Eng. Jour.*	New York, 45 Broadway; monthly, $3.

Vol. I, 1884.

Electrical Progress. Notes on Phenomena in Incandescent Lamps. (Illustrated.) Prof. Edwin J. Houston of Philadelphia.
Underground Wires. (Illustrated.) W. M. Salisbury of New York.
Spectroscope. (Illustrated.) Prof. Edwin J. Houston of Philadelphia.
The Delany Synchronous Multiplex System of Telegraphy. (Illustrated.) Prof. Edwin J. Houston of Philadelphia.
The Scientific City Sewerage. (Illustrated.) Col. Rowland B. Hazard of N. Y.
An Experimental Method of Studying the Dynamo Machine. By Prof. C. F. Brackett, of Princeton, N. J.
Railway Wires; or the Earth as an Electric Circuit Conductor. Thomas D. Lockwood, Boston, Mass.
Telegraphing without Wires—An Experiment. (Illustr.) S. J. M. Pear. Chemist of the Oakdale Filament. Edward P. Thompson, of New York.
Deposition Vats in "Series." H. B. Sisler, now of Detroit, Mich.
The Patent Office; its Relation to Inventors and its Needs. C. J. Kintner, now of New York.

Vol. II, 1885.

The Professions of Electrical Inventions. F. Jarvis, of Wash'n, D. C.
Court of Mines Inventions. Frank P. Mills, now of Ishpeming, Mich.
The Electric Arc Lamp Frictional Clutch. (Illustrated.) By Edward P. Thompson of New York.
Description of a Large Secondary Battery Plant for Central Commercial Distribution. E. P. Roberts, of Cheyenne, Wyo.
Delany's System of Pan Script Telegraphy. (Illustrated.) Prof. Edwin J. Houston of Philadelphia.

Vol. III, 1886.

Underground Electrical Systems. By Sidney F. Shelbourne.
The Great Tangent Galvanometer of the Cornell University. Prof. W. A. Anthony, now of Manchester, Conn.
Some Recent Advances in Telephony. (Illustrated.) Thomas D. Lockwood, of Boston, Mass.
The Patent Office and Patent Office Practice. A. C. Fowler, of N. Y.
Series Distribution in Telegraph Wires. F. W. Jones of New York. Containing a Synopsis, with references to 118 American and Foreign Patents for Inventions intended to overcome these difficulties.
Secondary Batteries for Light and Power. A. H. Elmer.
The Wire Gauge. Report of Committee.
Notes on Dynamo Insulation. Sidney F. Shelbourne.

Vol. IV, 1887.

Electric Street Cars. T. C. Martin, of New York.
The Practical Requirements of Small Motors. S. S. Wheeler, of N. Y.
Distribution of Electricity by Secondary Generators. Discussion by F. L. Pope, Dr. Otto A. Moses, Captain O. E. Michaelis, Prof. Elihu Thomson and others.
Secondary Batteries in Practice. E. P. Roberts of Cheyenne, Wyo.
Determination of the Temperatures Corresponding to the Different Coils of a Wire Resistance. Prof. W. A. Anthony, now of Manchester, Conn.
On the Best Basis for the Section of the Armature Arbmatures to the Maximum Output. Field Magnets. (Illustrated.) Dugald C. Jackson, now of Lincoln, Neb.
Notes Illustrative of Alternating Currents. (Illustrated.) Prof. Elihu Thomson of Lynn, Mass.
A Few Considerations on Electric Railways. T. C. Martin, of New York. (No author abstract.)
Quadruplex Telegraphy. J. A. Fowers, of Troy, New York.
On the Greatest Power Available by Means of the Temperature Coefficient of Some Various Substances. (Illustrated.) Prof. W. A. Anthony, of Manchester, Conn.
Arc Lamp Carbons. (Illustrated.) David Brooks, of Philadelphia.
The Electric Lighting of Passenger Trains. (Illustrated.) Geo. W. Bissell, of Boston.

"Every man is a debtor to his profession, from the which, as men do of course seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help thereunto."

LORD BACON.